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THE APPLICABILITY OF SATELLITE TECHNOLOGY TO DEFENSE CIVIL PREP--ETC(U)

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THE APPLICABILITY of SATELLITE TECHNOLOGY to DEFENSE CIVIL PREPAREDNESS

Final Report

Contract No: DCPAOI-77-C-0239

DCPA Work Unit 2214E

30 June 1978

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

COMSAT GENERAL CORPORATION
950 L'Enfant Plaza, Southwest Washington, D.C. 20024

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This study assesses the applicability of satellite technology to the DCPA mission. Surveys of currently-available and planned communication and remote sensing satellite systems are presented. A section on post-nuclear-blast propagation conditions is included. Conceptual satellite network plans, one based on a dedicated network and one on commercial transponder leasing, are developed, leading to a plan for a preliminary Demonstration Network. The study over

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Signal propagation
Warning dissemination

20. concludes that a satellite-based Civil Preparedness Communication Network could support both peacetime and disaster-oriented requirements practically; that the use of remote sensing for resource data base inventorying is presently inadvisible; that the 6/4 GHz band offers the best technical and most cost-effective means for initial implementation; and that use of remotely-located Sensor Monitor Terminals to collect and transmit radioactive fallout data to a central processing facility is feasible.

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for DEFENSE CIVIL PREPAREDNESS AGENCY
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DETACHABLE SUMMARY

1. INTRODUCTION

This document presents the results of a study performed by COMSAT General Corporation for the Defense Civil Preparedness Agency (DCPA) under Contract No. DCPA01-77-C-0239.

2. PURPOSE

The report contains an assessment of the applicability of satellite technology to the mission of DCPA. The study evaluates the requirements for peacetime and disaster communications in order to develop a preliminary demonstration network design plan.

3. DISCUSSION

The various categories of communications support in current use and envisioned by the DCPA as future needs were examined. A compilation based on DCPA source documents, personal interviews and on-site investigations is contained in Appendix A. These inputs form the basis for consideration of a consolidated civil preparedness communication system. A comprehensive examination of satellite systems, existing and planned, was undertaken to determine cost, availability and feasibility (see Appendix D). The use of the relatively abundant facilities in the 6/4 GHz band appears to be the most acceptable system currently available.

Appendix E contains information on the propagation conditions that can be expected following a nuclear blast. This data may prove invaluable when making the final selection of an optimal frequency band and modulation scheme for the Operational Network. It describes

the lower frequency bands as most susceptible to outages following a nuclear explosion; the lower the frequency, the longer the outage. Alternate modulation methods and higher frequencies can effectively eliminate this problem.

The various cost factors are examined in Appendix C. The availability of low-cost, field proven 6/4 GHz hardware provides an opportunity for early implementation of a DCPA demonstration network. Equipment for the 14/11 GHz band is currently being developed and should be available for consideration for the Operational Network.

All the above factors were used in developing the Conceptual Satellite Network plans presented in Appendix B. One of these plans would utilize transponders leased from commercial domestic satellite (DOMSAT) carriers for the space segment. The other describes a dedicated network which would include satellites specifically designed for the DCPA mission.

A plan for a preliminary Demonstration Network is drawn from these concepts. This model would become the basis, following an in-depth performance analysis, for a practical and economical evaluation network. It would employ several earth stations, sensor monitor terminals (SMTs) and a leased transponder space segment representative of the actual hierarchical elements in an operational system. The conclusion that the 6/4 GHz frequency band would best be used is based primarily on the current availability of low-cost, reliable hardware and space segment transponder leases in that band.

There are, of course, some problems associated with the selection of the 6/4 GHz band, perhaps the worst being frequency congestion and

the inherent difficulties in obtaining frequency clearances, but this is not considered to be an insurmountable problem.

The ultimate Operational Network is envisioned to be a mix between terrestrial and satellite facilities. The exact composition would be based on evaluation of the data collected from the Demonstration Network and the Operational Network Design Study, taking into consideration the unique characteristics of all available communication facilities.

4. CONCLUSIONS

1. The use of a satellite-based Civil Preparedness Communications Network is a flexible, practical and logical approach. A well-planned system could support both peacetime and disaster oriented requirements. This would include telegraph, voice and data service, fallout monitoring and the warning dissemination system.
2. The use by DCPA of currently available and planned remote sensing satellites for resource data base inventorying would be inadvisable at this time. Nor is currently-flown instrumentation suitable to detect and/or track nuclear fallout. However, the GOES ability to track dust clouds seems a potentially promising application which may profit from further study.
3. At this time, the commercial satellite 6/4 GHz band offers the best technical and most cost-effective means for implementing a Demonstration Network despite the problems of

frequency congestion. The availability of low-cost, reliable hardware and of commercial communications satellite transponder leases outweighs the unknown factors in the developing 14/11 GHz band. The ultimate system design need not be confined or directed toward any particular frequency spectrum at this time. The data obtained from the 6/4 GHz evaluation network, coupled with future hardware development and frequency allocation decisions will all play important parts in the design of the Operational Network.

4. On a small scale, the feasibility and practicality of utilizing remotely located Sensor Monitor Terminals to collect and transmit radioactive fallout data to a central processing facility is a viable and readily attainable alternative. COMSAT General Corporation is presently demonstrating this concept to the USGS with regard to hydrologic data.

5. Prior to the implementation of a demonstration system it will be necessary to perform a detailed study of procedural requirements, available operating frequencies, and physical plant arrangements. It will be necessary to perform surveys of the proposed location of earth stations and sensor monitor terminals in order to gain local and Federal approvals.

6. RECOMMENDATIONS

1. The preliminary Satellite Network Design Plan for a demonstration Network described in Appendix B should be used as the basis for inaugurating action to define the facility and link performance characteristics, hardware specifications, interface arrangements, procedural requirements and site data for a demonstration or pilot system.
2. An Operational Network study, based on an analysis of the long-term availability of satellite resources in all bands, as well as the DCPA requirements projected ahead for the next five to ten years, should be conducted. The study should anticipate technological advancements and after evaluation of the results of the demonstration phase, provide complete system definition and performance specification requirements for all elements of the Operational Network. The results of this study should provide a conclusive recommendation as to the appropriate approach for the Operational Network, comparing the use of a dedicated satellite system to the utilization of full-time leased transponders of an existing (or proposed) commercial satellite system as integrated into the Defense Civil Preparedness Communications Network.
3. The DCPA should evaluate the merits of using remote Sensor Monitor Terminals, as discussed in Appendix H, for the collection of fallout and associated environmental data.

The small-scale Sensor Monitor Network recommended as part of the demonstration system will provide experience and developmental information to assist in the full definition of the Operational Network.

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The various categories of communications support in current use and envisioned by the DCPA as future needs were examined. A compilation based on DCPA source documents, personal interviews and on-site investigations is contained in Appendix A. These inputs form the basis for consideration of a consolidated civil preparedness communications system. A comprehensive examination of satellite systems, existing and planned, was undertaken to determine cost, availability and feasibility (see Appendix D). The use of the relatively abundant facilities in the 6/4 GHz band appears to be the most acceptable system currently available.

Appendix E contains information on the propagation conditions that can be expected following a nuclear blast. This data may prove invaluable when making the final selection of an optimal frequency band and modulation scheme for the Operational Network. It describes the lower frequency bands

as most susceptible to outages following a nuclear explosion; the lower the frequency, the longer the outage. Alternate modulation methods and higher frequencies can effectively eliminate this problem.

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There are, of course, some problems associated with the selection of the 6/4 GHz band, perhaps the worst being frequency congestion and the inherent difficulties in obtaining frequency clearances, but this is not considered to be an insurmountable problem.

The ultimate Operational Network is envisioned to be a mix between terrestrial and satellite facilities. The exact composition would be based on evaluations of the data collected from the Demonstration Network and the Operational Network Design Study, taking into consideration the unique characteristics of all available communications facilities.

4. STATEMENT OF WORK

Provide a first phase study to include:

(1) a survey of the perceived needs for national civil defense communications;

(2) an assessment of currently available and planned satellite communications networks and their suitability for national civil defense communications;

(3) consideration of a ground environment (mobile, transportable and fixed communications stations) which would be compatible with existing and/or planned satellite communications networks and would fully or partially meet the needs of the Defense Civil Preparedness Agency;

(4) discussion of the relative merits of satellite networks in relation to alternate communications capabilities including consideration of a hybrid network;

(5) preparation of a preliminary design for a satellite based disaster warning and communication network;

(6) assessment of the application of remote sensing technology to the creation of a peacetime national resource data base, post-attack damage, and a comparison between the two;

(7) preparation of a plan for (a) in-depth analysis of the identified requirements and (b) design of demonstration/operational communication network to meet the perceived needs for civil defense communications including attack warning, damage assessment, emergency assistance and sustained recovery.

5. CONCLUSIONS

1. The use of a satellite-based Civil Preparedness Communications Network is a flexible, practical and logical approach. A well-planned system could support both peacetime and disaster oriented requirements. This would include telegraph, voice and data service, fallout monitoring and the warning dissemination system.

   The feasibility of utilizing satellite communications as a means for extra-terrestrial emergency communications was clearly demonstrated after the Johnstown Flood Disaster of 1977. While this example was valuable as a demonstration in that it was a true disaster situation, it did not prove full applicability of this technology to the DCPA mission.

2. The use by DCPA of currently available and planned remote sensing satellites for resource data base inventorying would be inadvisable at this time. Nor is currently-flown instrumentation suitable to detect and/or track nuclear fallout. However, the GOES ability to track dust clouds seems a potentially promising application which may profit from further study.

3. At this time, the commercial satellite 6/4 GHz band offers the best technical and most cost-effective means for implementing a Demonstration Network despite the problems of frequency congestion. The availability of low-cost, reliable hardware and of commercial communications satellite transponder leases outweighs the unknown factors in the developing 14/11 GHz band. The ultimate system design need not be confined or directed toward any particular frequency spectrum at this time. The data obtained from the 6/4 GHz evaluation network, coupled with future hardware development and frequency allocation decisions will all play important parts in the design of the Operational Network.

The planned hydrologic information service which COMSAT General intends to provide to the United States Geological Survey will operate in the 6/4 GHz band. The 14/11 GHz or 20/18 GHz bands could also be utilized, but signal attenuation due to rainfall and airborne debris becomes more serious at the higher frequencies. The 1.5-1.6 GHz and 7-8 GHz bands are presently limited in capacity, although frequency allocation decisions in this regard could make these bands more attractive. The entire area of procedural decision making, as it may affect the DCPA's efforts at improving its communication networks, requires further study.

4. On a small scale, the feasibility and practicality of utilizing remotely located Sensor Monitor Terminals to collect and transmit radioactive fallout data to a central processing

facility is a viable and readily attainable alternative. COMSAT General Corporation is presently demonstrating this concept to the USGS with regard to hydrologic data.

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APPENDICES

THE NATIONAL CIVIL PREPAREDNESS COMMUNICATIONS NETWORKS

1. GENERAL

This section provides a summary description for three of the four communication systems currently employed by the Defense Civil Preparedness Agency (DCPA) to meet national civil preparedness communications needs. The fourth communication system, the Civil Defense National Radio System, is essentially a secondary or backup system and is not discussed in this report. In addition, this section describes the DCPA's fallout monitoring network, which currently makes use of any available communication system. It responds to item (1) of the Statement of Work: "a survey of the perceived needs for national civil defense communications". The eight DCPA regions are shown in Figure A-1, which is supplied as a reference.

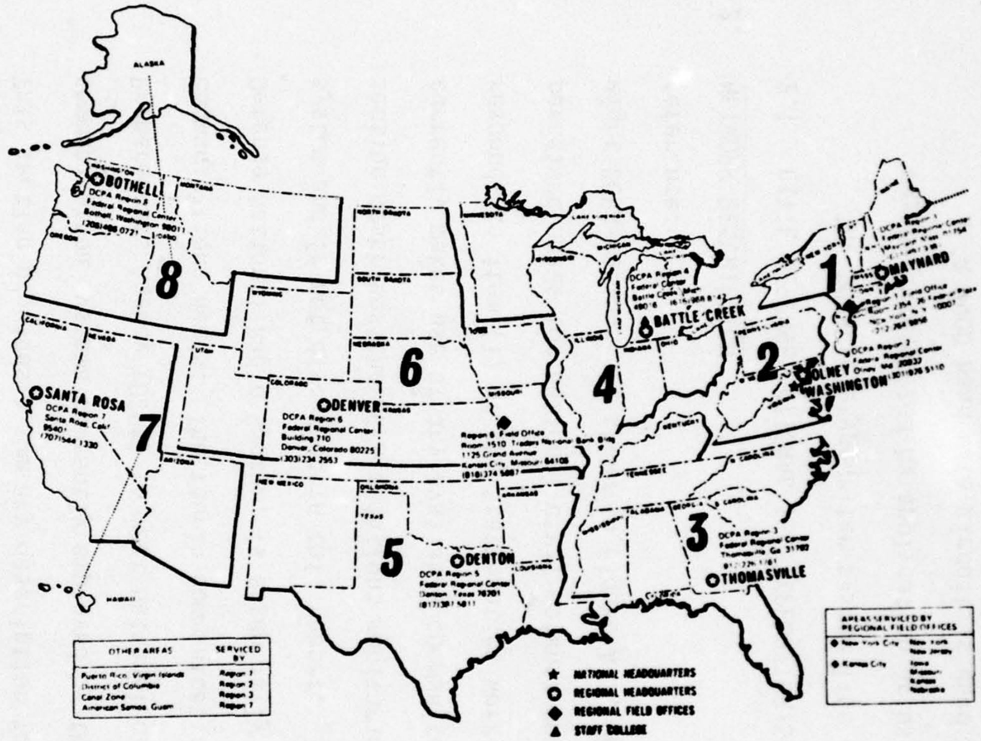
2. NETWORK DESCRIPTION

2.1. CIVIL DEFENSE NATIONAL TELETYPEWRITER SYSTEM

The DCPA teletypewriter system line and trunking requirements may be categorized by application or use (Figure A-2).

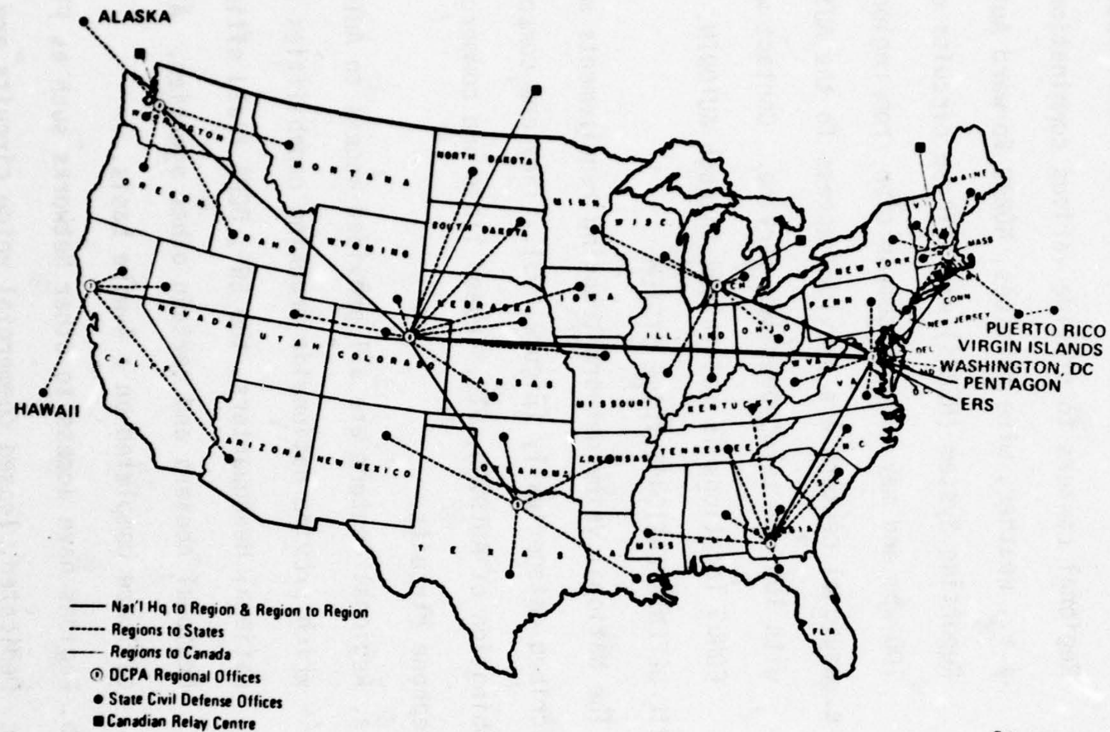
a. A 2400 baud data circuit is used to provide trunking between computers located at the two area centers located in Region two and Region six.

b. The Region two and six Area centers are connected to assigned regional centers via multiplexed 1200 baud trunks.



Source: DCPA

FIGURE A-1. DCPA Regions



Source: DCPA

FIGURE A-2. Civil Defense National Teletype System

c. Regional centers are linked to State centers and other agencies using full duplex 100 wpm teletypewriter circuits. Canadian Civil Defense Stations are connected to U. S. Regional centers by circuits operating at 50 wpm.

d. Receive-only teletypewriter service links appear at all Regional centers to provide various combinations of inputs, i.e., weather, wire services, NORAD Forward Automatic Reporting System (NFARS),etc. These circuits operate at 100 wpm and may vary in composition from region to region.

e. Regional centers are provided access to the AUTODIN system with 100 wpm teletypewriter service. Contact with some non-CONUS locations is maintained through AUTODIN.

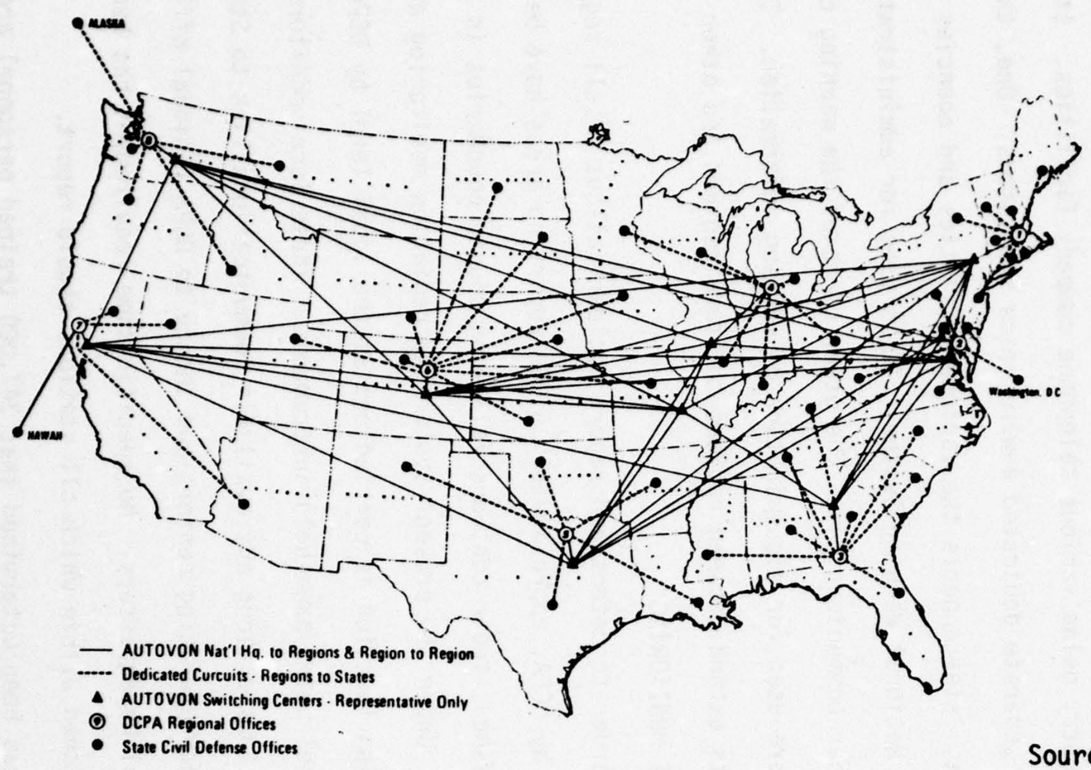
2.2. CIVIL DEFENSE NATIONAL VOICE SYSTEM

The National Voice network trunking requirements may also be described categorically (Figure A-3). They are composed of a combination of AUTOVON, FTS, leased lines and commercial dial telephone circuits.

a. Regional Centers are all provided access to AUTOVON switches which provide nationwide trunking capabilities between DCPA National Headquarters, the ERS, DCPA field offices, other Regional centers and certain other agencies. All AUTOVON call are completed on a 4-wire basis.

b. Regions have access to other networks such as FTS and NORAD.

c. Dedicated, leased commercial voice circuits are provided between the regions, the states, and other agencies.



Source: DCPA

FIGURE A-3. Civil Defense National Voice System

d. Commercial dial service is available at all locations.

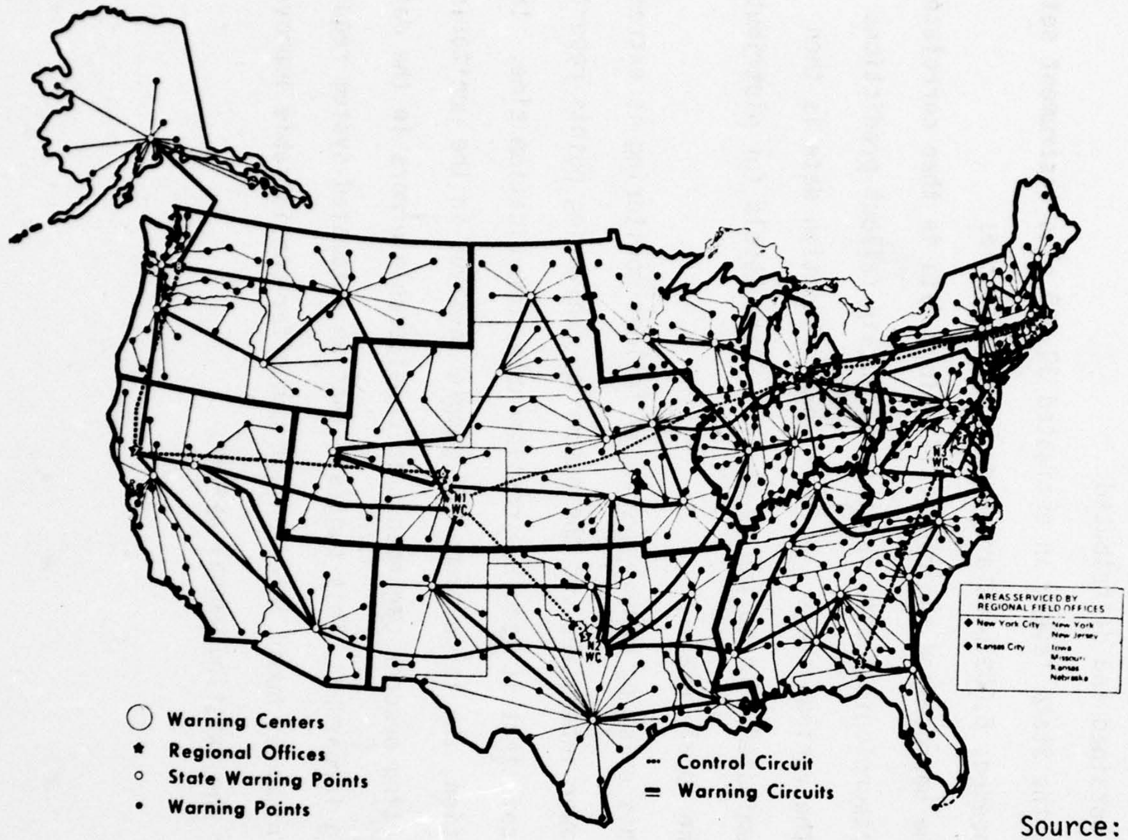
2.3. NATIONAL WARNING SYSTEM (NAWAS)

The NAWAS is a special purpose leased line network (Figure A-4). It provides terminations at approximately 2,000 locations throughout the country using various telephone company facilities. It consists of two separate dedicated 4-wire voice subsystems. One, the control circuit, interconnects the various facilities and agencies that make up the National Warning System. It is used for administrative voice and other communications. The other contains the warning circuits which are used for dissemination of warning information. These circuits extend between regions to State centers and other agencies.

2.4. FALLOUT MONITORING

In order to detect and report nuclear fallout in all regions served by DCPA, approximately 5,000 reporting areas have been established, their contours following county boundaries in most cases. Under the present system the radiation monitoring and reporting function is carried out at the local level by DCPA-trained personnel using hand-held instruments. These local monitors then report upward along any available communications link to State emergency operating centers and thence to DCPA regional offices and National Headquarters. No specific time requirement has been established within which all stations should report.

It has been determined that 347,000 trained personnel are needed to fulfill this function; of these, 83,000 are currently available and approximately 11,000 are trained annually.



Source: DCPA

FIGURE A-4. National Warning System

Local self-support monitors; i.e., firemen, policemen, require 90,000 sets of monitoring instruments, each consisting of 5 dosimeters, 2 high-range and 1 low-range survey unit, and a charge unit. Of these, 47,000 sets have been obtained and distributed.

At the State level, an estimated 30,000 plus instrument sets are needed; 6,000 plus are currently available.

The unprocessed radiological/fallout data is then correlated to meteorological data in order to obtain fallout predictions for the various areas. This fallout prediction data is then disseminated back to the Region and State levels for distribution at the local level.

This existing manual system of fallout monitoring is extremely manpower intensive, and the number of monitoring points reporting indicate that it requires considerable communication time. In addition, the large number of people involved in the monitoring/reporting process can result in considerable errors in the data being forwarded. This suggests that an automated system requiring a minimum of human intervention can offer considerable improvement over the existing manual system.

APPENDIX B

SATELLITE NETWORK DESIGN CONCEPTS

1. GENERAL

This section outlines a design concept for a satellite communication network capable of meeting civil preparedness requirements for both administrative and disaster communications in partial response to item (7) of the Statement of Work: plan for (a) in-depth analysis of the identified requirements and (b) design of demonstration/operational communication network..." The proposed network is based upon the implementation of a full-time leased transponder satellite system, and the use of medium-sized (11 meters) and small-sized (6 meters) earth stations located at civil preparedness offices and other designated sites.

An alternative to the basic network concept is also described. This alternative requires the use of a dedicated satellite communication system designed specifically for DCPA requirements. In addition, a Preliminary Demonstration Network Design Plan is presented as an Operational Network.

2. SATELLITE COMMUNICATION SYSTEM CONFIGURATIONS

Analysis of current civil defense communication systems, present and planned satellite communication systems, and operational environment considerations indicates that the most effective civil preparedness satellite communication system should utilize a satellite with the following characteristics:

a. Operation in the 6/4 GHz band;

b. Non-phase-encoded modulation;

c. Resistance to nuclear blast effects and enemy attempts at communications disruption;

d. Adequate backup and follow-on support.

None of the present or planned satellite systems studied for this report possesses all of these desired characteristics. Consequently, the preferred approach is to implement a system that comes closest to meeting requirements with a minimum of harmful trade-offs.

2.1. LEASED TRANSPONDER SYSTEM

A communication satellite system could be implemented by leasing a transponder on one of the commercial domestic satellites. None of the systems satisfies all requirements; therefore, it would be necessary to select a system for which the trade-offs have a minimal effect on the stated objectives. The least harmful trade-off that can be made would be to select a system that operates in the 6/4 GHz band, and thus be faced only with the difficulties of frequency congestion in urban areas.

The RCA Satcom, AT&T/Comstar, and Westar satellite systems offer the minimum trade-offs of stated objectives. They are currently available, and are expected to be available into the future, with appropriate backup. Frequency of operation and modulation techniques offer excellent resistance to nuclear blast caused propagation effects. They all operate at power levels which will permit the use of minimum size earth stations. As stated

previously, the RCA Satcom, AT&T/Comstar, and Westar satellites do present frequency coordination problems because of their operation in the 6/4 GHz band, but it is not an insurmountable problem.

Such a system would operate on a leased, protected transponder, utilizing medium-size earth stations at the Regional Headquarters sites (11 meters) and small earth stations at the State civil defense sites (6 meters). The system would use the single channel per carrier-companded frequency modulation (SCPC-CFM) type of modulation because it offers maximum system flexibility, minimum earth station complexity, and efficient use of the spacecraft capacity. It also offers good resistance to nuclear blast caused propagation effects.

Each SCPC channel would be a nominal 4 kHz voice channel, which can be configured for voice, plus up to five 75-baud teletypewriter channels. These channels may also be used to carry 1200-baud or 2400-baud data, or "Freeze-Frame" video for teleconferencing. An SCPC channel can be utilized to carry tone-encoded signals for use as part of the National Warning System.

The following represents the general link configuration. The actual Network arrangement would depend on the requirements existing when such a system is implemented. Changes in connectivities may be easily accommodated due to the inherent flexibility of the system.

a. Regions two and six, which serve as Area Centers, would be interconnected by a full duplex 2400-baud data trunk and two (or more) voice circuits.

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b. A full duplex 1200-baud link would be established between Regions two or six and each of the assigned Regional Centers. The Area Centers would also maintain two or more full duplex voice circuits to each of the Regional Centers within its area of interest.

c. Regional to State links would consist of one or more (based on need) full duplex voice-plus telegraph circuits.

d. The National Warning System would be comprised of SCPC channels which are assigned only for this purpose. One carrier would be transmitted by each of the National Warning Centers. The carriers would be continuously transmitted, and would each bear a pilot signal for continuous verification of circuit continuity. The warning carriers would be received by Regional and State offices, and if desired by the individual States, and may be received by the actual warning points. The receiving sites would automatically activate the local warning system, or alternatively allow manual activation of the warning system, when either of the carriers is activated with a warning code. It would be possible for the system to operate with more than one warning code to permit selective activation of the warning system, or to indicate different degrees of warning; i.e., pre-warning alert, etc.

e. Teleconferencing would be accomplished by use of voice-channel bandwidth "Freeze-Frame" techniques. This can be accomplished by preempting regular voice circuits, or by reserving a pool of frequencies in the satellite for this purpose. The latter method has the disadvantage that the earth stations would be more complex, but offers the advantage that other communication services would not be affected. The latter method would also permit any Regional office to teleconference directly with any other Regional office, as well as National Warning Centers.

The DCPA system would utilize medium-sized (11-meter) earth stations at the Regional Center sites, and small-sized (6-meter) earth stations at the State civil preparedness sites.

2.2. DEDICATED SATELLITE SYSTEM

The dedicated satellite system plan is based on using satellite(s) designed specifically to DCPA requirements, and for utilization only by DCPA. The dedicated system could operate in any of several frequency bands. The most desirable would be the subject of further study.

Network arrangements, modulation techniques, and available services would be the same as for the leased transponder system, the main difference being the use of a satellite optimized to the DCPA mission, and hardened against blast effects and enemy attempts

at disruption.

If such a system were implemented, it would require, in addition to the spacecraft and earth terminals, one or more stations for spacecraft tracking, command and control. These stations would be incorporated into the Region 2 and Region 6 terminals. The principal deterrent to creating such a dedicated system is the substantially greater costs.

Typical costs of earth stations, a dedicated satellite system, etc., are discussed in Appendix C.

2.3. PRELIMINARY DESIGN PLAN FOR A DEMONSTRATION NETWORK

A demonstration network can take several forms. An effective evaluation network must contain all the essential elements which will be used in the Operational Network. It would include voice and teletypewriter service, a disaster dissemination system that can be exercised on a national, regional or local level and a means for gathering fallout data for evaluation at a centralized collection point.

The demonstration network would consist of two Regional/National Centers, two or more State or Emergency Operating Center (EOC) facilities and a number of Sensor Monitoring Terminals. Terrestrial cable and radio interfaces would be used to simulate actual operating conditions. The space segment would require leasing of a transponder segment from one of the commercial DOMSAT carriers.

This network contains all the prescribed elements and would provide an effective and practical means for evaluation and analysis from which to base the operational network design.

There are, of course, alternatives. For technical or economic reasons, the network requirements may be evaluated in stages, then collectively analyzed. For example, the fallout monitoring requirement, while large in final form, could be effectively evaluated with only 6 - 10 Sensor Monitor Terminals operating through an existing DOMSAT facility. The National Warning System, Voice and Data Service could be similarly evaluated.

2.3.1. Geographical Considerations

The DCPA Demonstration Network would include at least two Regional/National facilities, one located in Olney, Maryland (Region 2), or Thomasville, Georgia (Region 3), and the other in Denton, Texas (Region 5). The State centers and related sensor monitors may be sited at convenient locations anywhere within the "footprint" of satellite coverage areas. These terminals would be relocatable and could be redeployed to various locations during the demonstration phase.

2.3.2. Cost Information

Appendix C contains a discussion on the basic cost elements which may be used to provide a budgetary planning estimate for the Demonstration Network. The abbreviated Network depicted above could be implemented for 2 - 3 million dollars, including space segment charges for a six-month demonstration period. A breakdown of

the costs are contained in Table B-1. The bulk of the earth station assets are recoverable and may be used in the Operational Network.

TABLE B-1

COST DATA

CIVIL PREPAREDNESS DEMONSTRATION NETWORK

	Quantity		
Regional Earth Stations	2	350K	700K/900K
State/EOP Earth Stations (Mobile)	2	270K	500K/600K
Sensor Monitor Terminals	10	10K	90K/110K
Sensors	10	2K	18K/22K
Test Equipment	Lot	160K	180K/260K
Installation*	Total	160K	160K/200K
Misc., Terrestrial Links	Lot	60K	50K/70K
		Subtotal	1698K/2162K
Space segment charges for six months (unprotected)			500K/500K
		Total	2198K/2662K

*Exclusive of land, permits, fees, O&M, etc.

K = Thousands of Dollars

APPENDIX C

COST DATA

1. GENERAL

This section contains cost estimates for the components of the proposed Civil Preparedness Communications Network. The costs provided are subject to wide variations depending upon detailed design parameters of the actual system. The costs are based on current dollar values and do not consider increases due to inflation or other factors.

2. LEASED TRANSPONDER NETWORK

The use of a leased transponder for the space segment is presently estimated to cost between $1,000,000 and $1,700,000 annually. The exact price is dependent upon when and from whom the transponder is leased and whether the service is protected or not. Protected service means that in the event of failure, a second transponder is available immediately for use. It is assumed that protected service will be required and therefore that $1,700,000 is the applicable annual lease cost.

The DCPA Satellite Communication Network would consist of two types of earth stations. Regional terminals and small State terminals. The cost of procuring a fully-equipped Regional station is estimated at $500,000. The State terminals, in quantity, would cost approximately $120,000 each. When mobile facilities are desired for the State terminal, add $150,000 per station. Test equipment for a fixed

Regional station would cost $130,000; the State terminal test equipment cost is estimated at $50,000 per station. Installation of a Regional Station is costed at $80,000 per station and the State terminals at $20,000 each.

It is assumed that all land, sites, office facilities, and prime electrical power are available at no cost. All stations considered herein are based upon commercially available equipment built to best commercial practice, and not hardened or specifically modified to meet the needs of DCPA. These cost estimates will increase significantly if hardening is a requirement.

Operation of the network is visualized as being a function of the user, in the sense that the station will be unattended, and the user will simply activate a teleprinter, telephone, facsimile machine, or other instrument, to automatically establish a circuit. Responsibility for maintenance and repair would be assigned to a mobile maintenance team based at National Headquarters. This team would be comprised of six to twelve technicians, and would be dispatched as necessary to effect repairs and to perform routine maintenance. All of the equipment is redundantly configured, so there is a very low probability of service interruption.

As mentioned previously, all estimates are in current dollar values and assume that land, office and prime power charges are borne elsewhere.

3. DEDICATED SATELLITE NETWORK COSTS

The implementation of a dedicated satellite network is a costly venture. To design and build three satellites (one in-orbit operation, one in-orbit spare, one backup for launch failure) specifically tailored to

DCPA requirements is estimated to cost $60,000,000 to $120,000,000. Each satellite launched will represent an investment of $35,000,000, assuming a satellite ready-to-launch cost of $20,000,000, and a launch utilizing a combined load configuration of the space shuttle at a cost of $15,000,000. It is assumed that it will require three launches to establish an in-orbit operational satellite and an in-orbit spare, producing a total expenditure of at least $105,000,000 and perhaps as much as $165,000,000. This cost would be amortized over a projected satellite life-time of 7 years.

With a dedicated high-power satellite in orbit, the earth station design could be simplified, and the size of the antennas reduced. Optimistically, the reduction could lower the earth segment investment. However, in addition to the communications earth stations, it is also necessary to implement two telemetry, tracking and command (TT&C) stations.

4. DATA COLLECTION NETWORK

The costs associated with the data collection network, for fallout monitoring, are dependent upon whether a dedicated data collection platform system is deployed, or whether an information service is utilized.

The cost of a dedicated data collection platform is estimated to be $10,000 per platform.

APPENDIX D

COMMUNICATION SATELLITE SYSTEMS

1. GENERAL

This section responds to item (2) of the Statement of Work, providing "an assessment of currently available and planned satellite communications networks and their applicability for national civil defense communications". This assessment is limited to domestically owned satellite networks. Foreign owned satellite networks will not, in all probability, be available to the United States in the event of a nuclear attack and, therefore, are not discussed in this section.

Two types of commercial satellite leases are currently available. One provides services on a private line or tariff basis. All of the equipment used belongs to the carrier. The other category, which is available on Western Union's System, permits leasing of the space segment. The provisioning of ground station equipment becomes the responsibility of the user.

DCPA communication requirements could be met by one or more of the existing or planned commercial domestic communication satellite systems. These systems have a demonstrated ability to provide high quality communication links at low cost, particularly over long distances. Satellite systems that could offer the required services are Western Union Westar, Satellite Business Systems, RCA Satcom, and COMSAT General/AT&T Comstar. The applications Technology Satellite (ATS-6) and Communications Technology Satellite (CTS) are

not commercial satellites, but since they can have application, they are also considered. Other communication satellite systems, which do not have application, are also briefly described.

2. SYSTEM DESCRIPTIONS

2.1. WESTERN UNION WESTAR

The Westar series of satellites operates in the band of 5925 to 6425 MHz for up-link frequencies and 3700 to 4200 MHz for down-link frequencies. Capacity of each satellite is 12 one-way video channels, or 7200 frequency division multiplex (FDM) two-way voice channels, or combinations thereof.

The Westar configuration best suited to DCPA requirements is a leased transponder, using companded single channel per carrier-frequency modulation (SCPC-FM) techniques. A number of carriers within the transponder bandwidth could be configured for low capacity portable terminals, for use after a disaster. A portion of the transponder bandwidth could be configured for slow-scan or fixed-frame video for use in two-way teleconferencing.

A single dedicated carrier frequency, with appropriate encoding, could serve to automate the National Warning System. It would be transmitted from a single headquarters site (with appropriate backup at one or more sites) and be received at any or all points within the network.

The Westar satellites are visible to the Continental United States (CONUS), Alaska, Puerto Rico, and the Virgin Islands. Hawaii is visible, but in a lower level spot beam, thus limiting the minimum antenna size. Guam is not visible to Westar.

Approximate Westar transponder leasing costs are as follows:

Type of Service	Cost
Monthly, unprotected	$120,000/Month
Monthly, protected	$180,000/Month
Yearly, unprotected	$100,000/Month
Yearly, protected	$142,000/Month

Widespread use of the 6/4 GHz frequency bands by existing satellite and terrestrial networks, particularly in urban areas, has resulted in frequency coordination problems, and may make it difficult for Westar to be applied to DCPA requirements in or near major cities.

2.2. RCA SATCOM

The RCA Satcom series of satellites operates in the 5925 to 6425 and 3700 to 4200 MHz bands and has a total of 24 transponders each. This gives a total per satellite capacity of 24 one-way video channels, or 12,000 FDM two-way voice channels, or combinations thereof.

The services available from RCA Satcom are: Private leased-channel voice and 9600 baud data, digital data service for 19.2 Kb/s to 1544 Kb/s, government private line service for data between 56 Kb/s and 3.08 Mb/s with higher data rates being implemented, private switched network service, and television and radio program distribution. The majority of this service is interconnected via existing commercial land-line facilities to the

nearest RCA Satcom earth station. There exists a limited number of government-leased private data-line channels which could be used for direct access to the satellite, via a close-located earth station, thus bypassing the commercial land-lines facilities.

If DCPA is limited to access via land-line facilities, the RCA Satcom appears to offer little or no improvement over the existing network. However, should direct access become possible, the RCA Satcom would be attractive and could be operated in the mode described under the Westar Satellite.

RCA Satcoms are visible to CONUS, Alaska, Hawaii, Puerto Rico, and the Virgin Islands. RCA Satcoms are not visible to Guam.

Approximate transponder leasing costs, on full-time, fixed-term (2 years) basis are as follows:

Start of Lease	Cost
May-October 1978	$65,000/Month
November 1978-April 1979	$73,000/Month
After May 1979	$83,000/Month

The frequency coordination problems associated with use of the 6/4 GHz band, described under Westar, also apply to RCA Satcom.

2.3. SATELLITE BUSINESS SYSTEM (SBS)

The SBS satellite will provide 10-transponder time division multiple access (TDMA) capability.

The SBS will operate with 14,000 to 14,500 MHz up-link frequencies and 11,700 to 12,200 MHz down-link frequencies.

SBS capacity is difficult to specify because of its dependence upon the network configuration, which is not yet fully defined. It is at least equivalent, however, to other domestic systems. SBS offers the advantage of direct service to customer on a demand basis. The services being offered are facsimile, high-speed data, voice, video, and teleconferencing. The entire SBS network is digital; ile., using TDMA techniques, except for any leased transponder portions.

This could be a very attractive system, and could satisfy all of the DCPA non-emergency requirements within CONUS. The system is designed primarily to satisfy high density users, but on a leased transponder basis it could be tailored to DCPA requirements.

The normal SBS service utilizes phase-shift-keyed type of modulation, and suffers from the additional disadvantages that rapid phase scintillation of the carrier following a high altitude nuclear detonation will degrade the bit error rate (BER) to unacceptable levels for approximately five hours or more. This effect can be expected to affect any phase encoded modulation scheme. If a single transponder is leased and used with other types of modulation, the phase scintillation problem would not be significant.

Transponder lease costs have not yet been determined by SBS. Also, SBS has not made any decisions yet regarding their willingness

to operate on a leased transponder basis.

2.4. COMSAT GENERAL/AT&T COMSTAR

The Comstar series of satellites, operating in the 5925-6525 MHz and 3700-4200 MHz bands, forms part of the AT&T Long Lines carrier network and initially functions primarily as part of the switched telephone system.

Each of the three operating satellites in this series offers a minimum capacity of 1500 FDM/FM voice/data channels per transponder, or with 24 transponders per satellite, an equivalent of 18,000 two-way circuits. The transponders can operate in either the TDMA or FDMA multiple-access mode; mixed mode operation is also conceivable.

AT&T traditionally provides user-to-user tariff service only. Their willingness to provide service on a leased transponder basis has not yet been determined.

2.5. INTELSAT

INTELSAT is the leading international communications satellite system. INTELSAT provides the majority of international satellite communications links in the world today, plus a limited amount of domestic communication links for a number of countries. The current series of INTELSAT IV-A satellites operates in the 5925 to 6425 MHz and 3700 to 4200 MHz bands, each satellite having a capacity of approximately 6,000 two-way voice and two one-way television channels. Future INTELSAT satellites will also operate in the 14,000 to 14,500 MHz and 10,950 to 11,700 MHz bands, with

substantially greater capacity. INTELSAT satellites are positioned over the three major ocean regions of the world, thus making it possible for INTELSAT to provide the required communication link to Guam and other outlying regions.

2.6. MARISAT

MARISAT provides commercial ship-to-shore two-way communications for the maritime industry. Up-link frequency bands are 1638.5 to 1642.5 MHz and 6420.0 to 6424.0 MHz. Down-link frequency bands are 1537 to 1541 MHz and 4195.0 to 4199.0 MHz. MARISAT is unsuitable for DCPA requirements due to its highly specialized design and geographical location which does not provide CONUS coverage.

2.7. APPLICATIONS TECHNOLOGY SATELLITE (ATS-6)

The communications portion of the ATS-6 satellite is intended for communication experiments in various frequency bands. It has three video capacity channels capable of receiving and transmitting in various combinations of C, S, L, and UHF frequency bands. It also has the capability for radio propagation experiments at various centimeter and millimeter wavelengths. The ATS-6 has been designed in a manner different from earlier spacecraft designs in that high complexity has been placed into the spacecraft hardware in order to minimize complexity of earth-based hardware.

ATS is intended as an experimental satellite, and is not available to users on a full-time lease basis. There have been

instances, however, when ATS was made available to non-experimental users to satisfy emergency communication needs. However, these must be considered exceptions.

This means that ATS cannot be used as part of the regular civil preparedness communication network, but it could be a part of a post-disaster contingency plan. However, the lack of backup or program follow-on makes long-term continued availability uncertain.

2.8. COMMUNICATIONS TECHNOLOGY SATELLITE (CTS)

CTS is a joint U. S./Canadian experimental venture, operating in the 14/12 GHz bands. Its main purpose is to demonstrate the feasibility of transmitting high-quality color television signals to small ground antennas, some as small as 32 inches in diameter. Use of a 200-watt TWT transmitter makes it the most powerful communications satellite ever designed.

Provision has been made for U. S. and Canadian experimenters to utilize the satellite on alternating days. To date, U. S. experiments have been in such areas as education, health care, and disaster-relief services.

As with the ATS, its experimental nature precludes full-time leased utilization. Again, as with the ATS, no provision has been made for backup or a follow-on satellite.

However, there remains the possibility of using the CTS as part of a post-disaster contingency plan.

2.9. TRACKING AND DATA RELAY SATELLITE SYSTEM (TDRSS)

The TDRSS will become a part of the NASA Spaceflight Tracking and Data Network (STDN), and will be managed and operated by Western Union. TDRSS will improve the STDN by providing an in-orbit relay for space-to-space-to-ground communication links. It will operate in the 2.5 and 14/11 GHz frequency bands.

The TDRSS is presently undergoing implementation and is expected to be operational in the 1980 to 1981 time period. Two planned TDRSS satellites will provide visibility to the entire Atlantic and Pacific Ocean regions.

A third TDRSS satellite will be positioned over CONUS, and will provide coverage in the 14/11 GHz band. However, it utilizes a phase encoded modulation scheme, similar to the SBS satellite, and will be subjected to the same phase scintillation problems described under SBS.

2.10. SYNCOM IV

The Syncom IV is a demonstration satellite proposed by the manufacturer to NASA as a space-shuttle-optimized communications package. Launch is expected in the first quarter of 1980. It is proposed to transmit communications at 14 GHz and, given the experimental nature of the satellite, receive at 2.5 GHz. The 6/4 GHz frequency band will be used for telemetry and control only.

2.11. MILITARY SATELLITES

The military satellites offer a degree of resistance to damage and jamming. Present military satellites (FLTSATCOM and DSCS II) operate in the UHF (225 to 400 MHz) and SHF (7 to 8 GHz) bands.

They offer moderate resistance to damage and jamming attempts. It is difficult to state their channel capacities because they are dependent upon a changeable mix of earth station configurations.

Later series of military satellites (DSCS III) will offer greater resistance to damage and jamming. The military satellites are positioned over ocean areas, and individually do not provide full CONUS coverage. However, coverage is sufficient that the Atlantic and Pacific satellites do have beam overlap within the United States, thus providing more than half CONUS coverage for each ocean region satellite.

The ability to accommodate non-military users on these satellites is very limited.

3. <u>ORBITAL POSITIONING OF SATELLITES</u> (See Figure D-1)

Known U. S. satellites are geographically positioned within the equatorial geostationary orbit arc between the longitudes of 70°W and 190°W. The longitudes extend beyond that of New York on the east and Los Angeles on the west. While this arc is occupied by both commercial and government satellites, the military satellites (DSCS- II & III, TDRS, NATO-3B, and FLTSATCOM) occupy the extremities while the commercial satellites of potential relevance to this report (SATCOM, WESTAR, SBS, COMSTAR) are grouped well with the interior of the arc.

The military satellites are used primarily for intercontinental and transoceanic communication while the domestic commercial communication satellites are positioned so as to provide communications primarily within the interior of the U. S., thus the difference in the orbital positioning. The longitudes of four U. S. cities are shown to indicate the relative positioning of the arc.

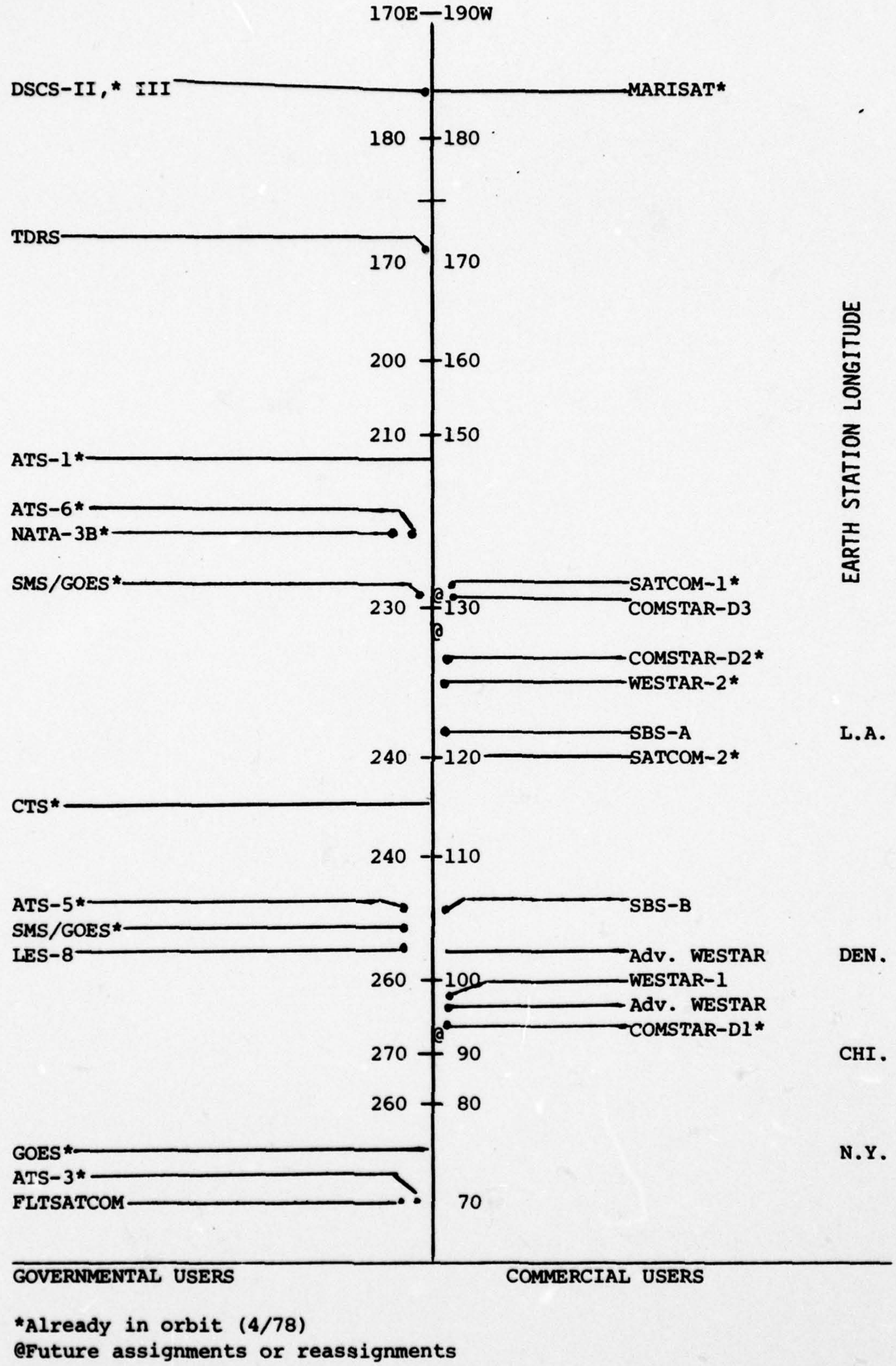

FIGURE D-1. ORBITAL POSITIONING OF U. S. GEOSTATIONARY SATELLITES

NUCLEAR BLAST EFFECTS

1. GENERAL

Appendix E was produced as a necessary preliminary portion of item (7) of the Statement of Work: "the preparation of a plan for (a) in-depth analysis of requirements and (b) design of demonstration/operational communications network..." It provides an analysis of the effects of a nuclear explosion on individual satellite channels of existing and planned satellite communication networks. Frequencies of the communication channels studied ranged from 225 MHz to 18 GHz. The analysis is limited to the effects caused by disturbances to the propagation medium and those caused by the electromagnetic pulse (EMP) generated by a nuclear blast. Structural effects caused by radiation (thermal, gamma, etc.) on the individual components of a satellite communication network are beyond the scope of this analysis which assumes as a precondition that the network survives the blast.

Because adequate data can be obtained for only a few observed nuclear explosions; e.g., "Checkmate" and "Kingfish" tests, the calculated worst-case values may be in error, especially values for long-term effects such as phase scintillation. These worst-case values are, however, state-of-the-art predictions.

2. NUCLEAR BLAST EFFECTS ON THE PROPAGATION MEDIUM

The following phenomena are known to affect the propagation medium following a nuclear blast: signal attenuation, dispersion, multiple

ray paths (multipaths), polarization rotation, doppler shift, refraction, noise and scintillation. With the exception of scintillation, all of these phenomena are of short duration, on the order of seconds or tens of seconds and are likely to prove inconsequential to system reliability. Phase scintillation, on the other hand, can affect phase encoded digital communication systems for up to 5 or 6 hours, depending on the yield and altitude of the blast.

2.1. SIGNAL ATTENUATION

Absorption of energy is the major source of attenuation immediately following detonation. It is produced by the dramatic increase in ionization levels within and near the perimeter of the fireball. Absorption has its greatest effect on frequencies lower than those normally used in satellite communication networks. The absorption level depends greatly on the location of the communication channel relative to the burst point and is of most concern when the fireball is directly in the transmission path. In this case, the electron density will reach a level on the order of $10^{19}/cm^3$, causing a temporary blackout followed by reduced system performance before normal conditions return.

$$A = \frac{N_e}{(f)^2}$$

f = carrier frequency in MHz

N_e = electron density/cm^3

Curves of attenuation versus time after burst are given in Figure E-1 for the frequencies of interest. This is the approximate total absorption for the entire path. Results show that considering a maximum fade margin of the order of 9 dB, direct attenuation is likely to be a concern for time periods of, at most, approximately one minute. Calculations show that absorption due to other causes; e.g., thermal ionization, beta particle ionization within the cylindrical debris region and outside the fireball are of the same approximate order of magnitude or less with roughly the same time dependence and can be ignored for the purposes of this report.

2.2 DISPERSION

Dispersion effects on a gaussian pulse that is propagating through an ionized medium can cause pulse distortion and loss of pulse bandwidth. Assuming that

$$f(f) = A_0 \exp \left(\frac{-t^2}{2\sigma^2} + i\omega t\right)$$

and $\Delta f = 1/4\sigma$, there can be as much as a 10 percent loss in bandwidth for a frequency of 225 MHz when the electron density integrated over the propagation path is approximately 10^{18} electrons/cm^2. This density is not likely to persist more than 10 seconds following detonation. Dispersion effects at higher frequencies are proportionally less.

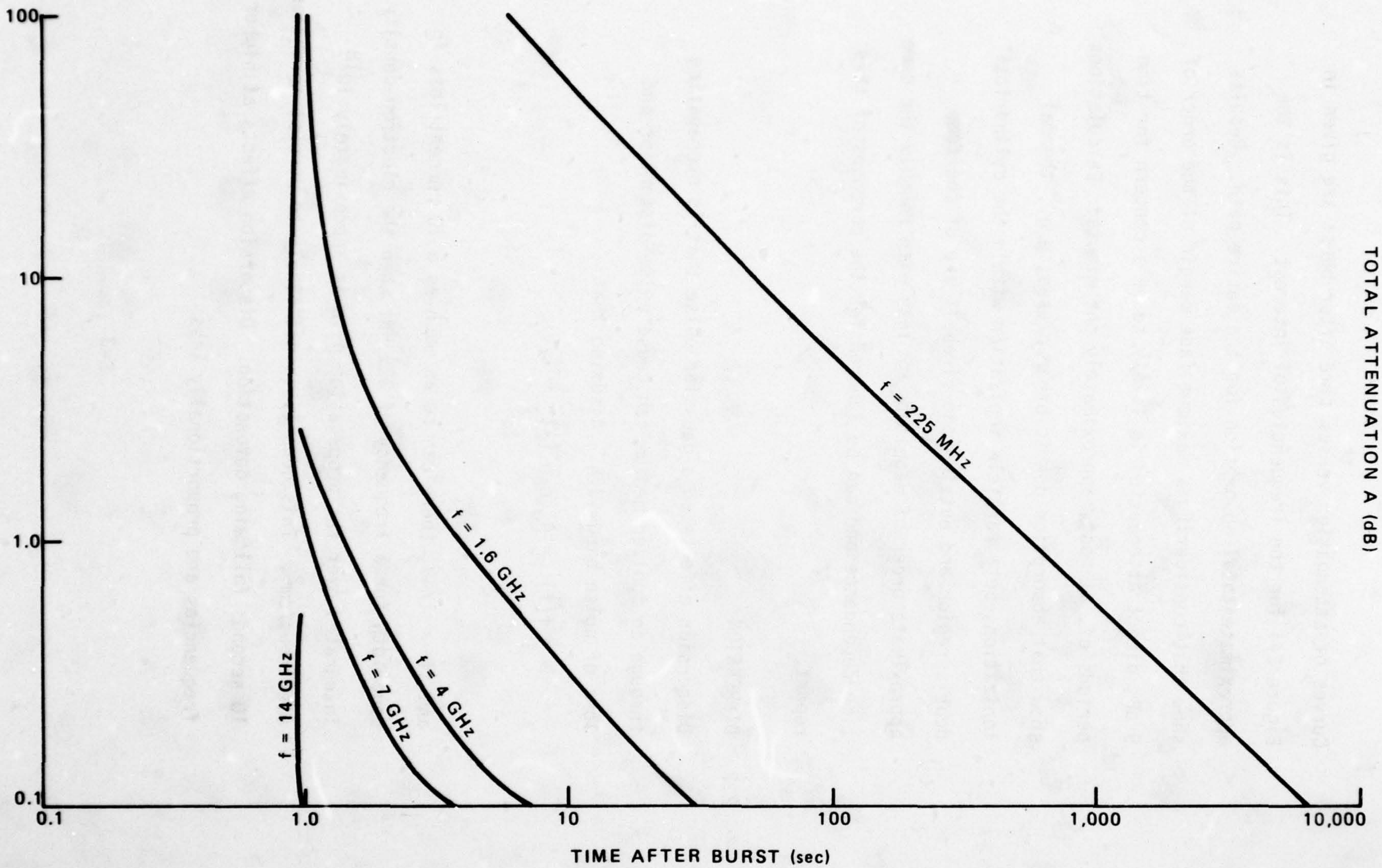

FIGURE E-1 TOTAL SIGNAL ATTENUATION DUE TO PROMPT IONIZATION

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2.3 MULTIPATH

A necessary condition for the existence of multipath (multiple ray paths) through an ionized medium is the existence of non-linear density gradients transverse to the propagation which can lead to focusing, defocusing and beam wander. This is ordinarily not of concern for frequencies above 10 MHz. In regions where the change in refractive index per wavelength is small, Fermat's principle of geometrical optics can be applied; and solutions for multiple ray paths can be derived for a smooth variation in electron concentration (N_e) as in the unperturbed ionosphere. Small-scale fluctuations due to turbulence, striations, etc., as would arise following a nuclear blast would disrupt this ordinarily smooth variation of N_e with height and make the possibility of significant phase error due to multi-path negligible.

2.4 POLARIZATION ROTATION

Faraday rotation of the signal polarization can be severe for a very short time. Typically for $f > 40$ MHz.

$$\Omega = \frac{(9 \times 10^3)^2}{2} \frac{\omega p \cos \phi}{cf^2} \int_o^s N_e ds$$

$$\omega_p = \frac{eB}{m}$$

where

ω_p = the electron cyclatron frequency (s^{-1})

B = magnitude of magnetic field (G)

ϕ = angle between direction of propagation and magnetic field (deg)

Ω = cumulative rotation (rad)

e,m = electron charge and mass (coulombs, kg)

$\int_0^s N_e ds$ = integrated electron density along the ray path

At f = 225 MHz, this is a few radians for a period of about 10 seconds. This will initially produce loss of polarization, but ambient conditions will return very rapidly. Long-term fluctuations are not significant enough to be of concern.

2.5. DOPPLER SHIFT

Frequency shift due to the doppler effect is likely to cause loss of signal only for the first few seconds after the blast. According to Knapp,

$$D \sim \frac{(9 \times 10^3)^2}{2cf} \frac{d}{dt}\left[\int_0^s N_e \, d_s\right] \text{ Hz.}$$

For the first second or so, the time rate of change of the electron density integral is very large and not very well known. Thereafter, the dependence is about 1/t making the doppler shift approximately 10^{-10} Hz or less, which can be assumed to be negligible.

2.6 REFRACTION

Refraction of electromagnetic waves in an ionized medium can be calculated by

$$m \sim \left(1 - \frac{N_e}{10^4 f^2}\right)^{1/2}$$

where

m = the ordinary index of infraction

N_e = electron density/cm^3

f = frequency (MHz)

Immediately after the blast, electron densities of the order of $10^{18}/cm^3$ will produce significant refraction errors (>10°), even at 18 GHz. These errors will last for a few milliseconds. After the first second the maximum electron density level reaches a saturation level of about $10^7/cm^3$ decaying as 1/t after that. For f = 225 MHz, $N_e f^2 \sim 10^{-10}$, the refractive error is of the order of a degree or less after one second (Refer to Figure E-2).

2.7 NOISE

The two most significant sources of noise from a nuclear blast are thermal radiation from the fireball itself and synchrotron radiation from beta particles traveling along the geomagnetic field lines. Other effects such as the Bremsstrallung effect and the Cerenkov effect are negligible. Synchrotron radiation is important at low frequencies only because it is long lasting. Ionized particles trapped along the geomagnetic field lines will oscillate between the magnetic "mirrors" at the two geomagnetic poles and radiate a significant level of noise for frequencies less than about 100 MHz. This effect will last as long as a few days and extend over a very wide area around the blast. For the frequencies of interest the magnitude is insignificant.

After a nuclear weapon is detonated, temperature equilibrium is rapidly established. Within about one microsecond after the

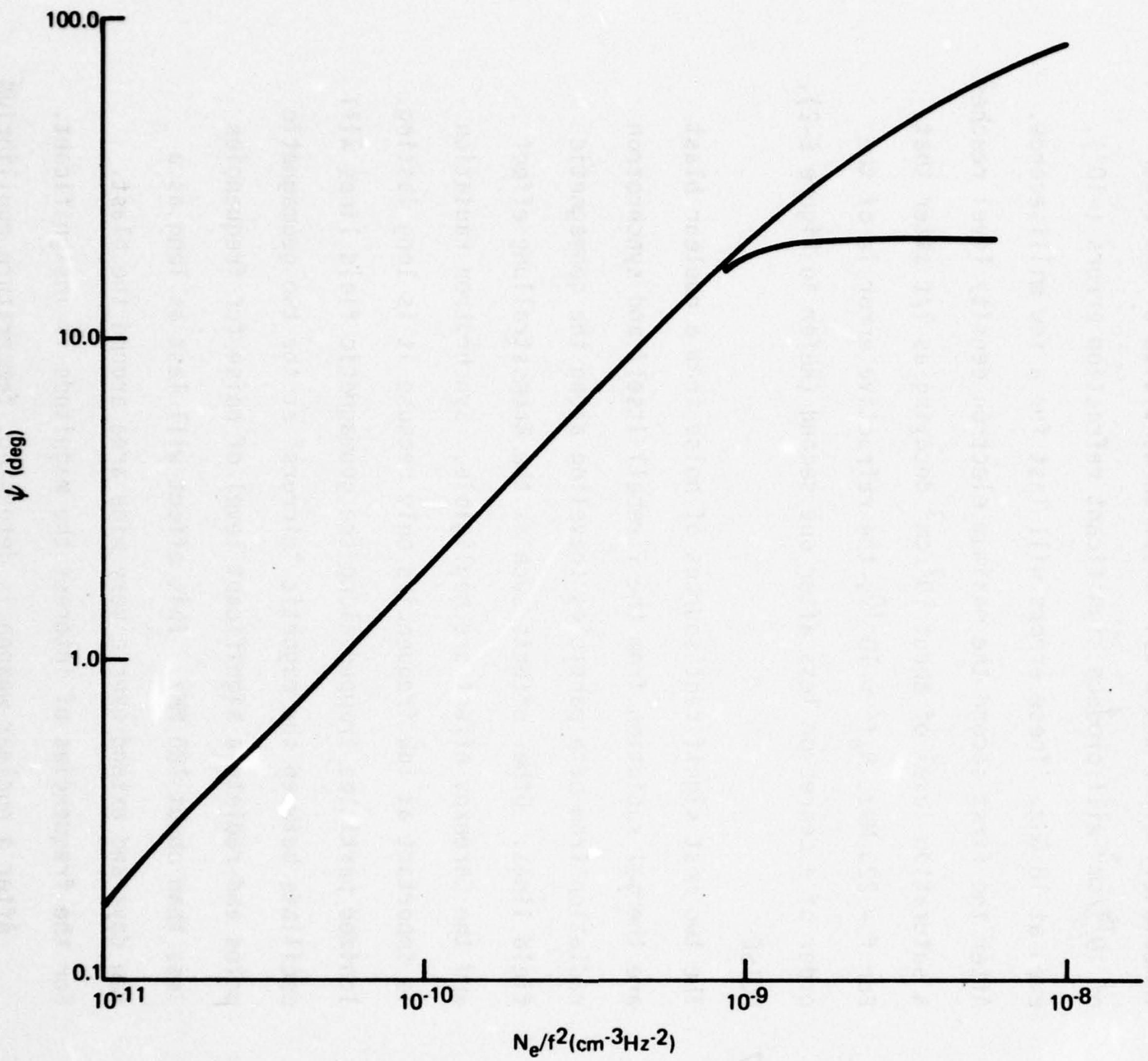

FIGURE E-2 REFRACTION ERROR IN A SPHERICALLY STRATIFIED MEDIUM

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explosion, some 70 to 80 percent of the explosion energy is emitted as primary thermal radiation. Almost all of the remainder is in the form of kinetic energy of the weapon debris at this time. The interaction of the primary thermal radiation and the debris particles with the surroundings will vary with the altitude of burst and determines the portion of energy received at a distance.

There are two high surface-temperature thermal pulses: one of short duration, the other much longer. The first lasts a few microseconds with very high surface temperatures. An estimate of the surface temperature at a terrestrial antenna in the vicinity of a low-altitude burst viewing the fireball is given as a function of time in Figure E-3, showing that temperatures above ambient will occur typically for about five minutes. The second lasts several seconds; e.g., about 10 seconds for a 1-megaton explosion. Since the temperatures involved are quite high (several million °K) and the time periods are so short, it is probable that physical damage to the satellite's receiving earth station will be more of a concern than any interference effects due to increased thermal noise levels.

2.8 SCINTILLATION

By far the most important long-term nuclear blast effect is rapid phase scintillation of the carrier due to fluctuations in the residual electron density across the satellite channel. High

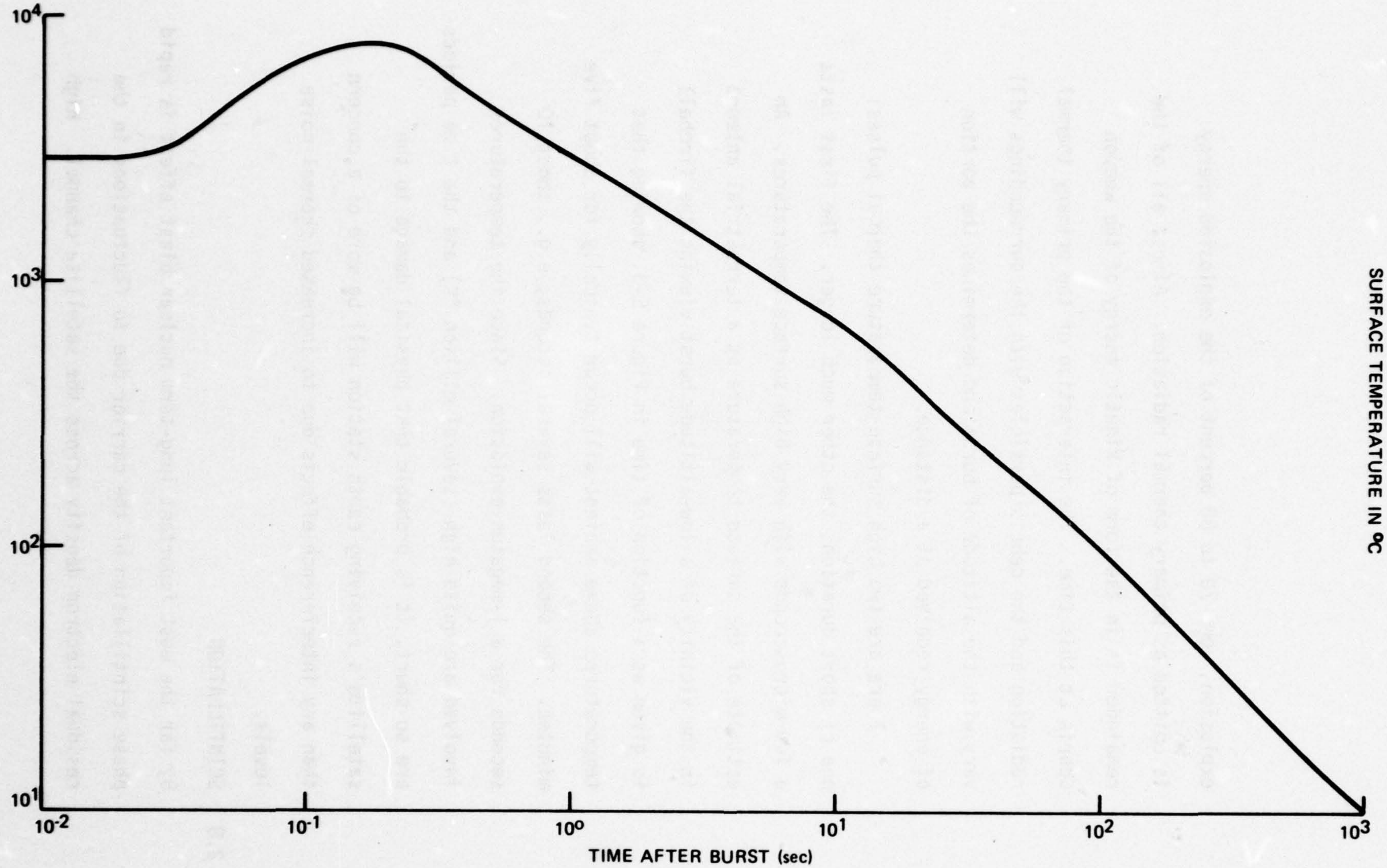

FIGURE E-3 APPROXIMATE TIME DEPENDENCE OF THERMAL RADIATION IN THE VICINITY OF A LOW-ALTITUDE 1 M-TON BLAST AS VIEWED BY A TERRESTRIAL ANTENNA TWO MILES AWAY.

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altitude detonations (>100 Km) cause the electron density structure to become striated, or layered through a very large region. Tropospheric phase fluctuations normally are much greater than ionospheric phase fluctuation and low altitude bursts may produce greater and longer lasting phase scintillation; however, the region over which this effect may be observed is considerably smaller than at higher altitudes. Scintillation of amplitude and angle-of-arrival are also significant but have a less detrimental effect on the system. The primary problem is that these phase scintillations remain at a significant level for a long time after other propagation disturbances have since become negligible. The range is also immense. One high-yield blast can provide enough scintillation fading to cause a degradation in performance over an area as large as the contiguous U. S., multiple blasts even more. Considerable evidence exists that striation of electron density and the resulting signal scintillation are real. However, much of the experimental data on nuclear situation phenomenology is photographic and difficult to interpret in a quantitative manner. Theoretical models involving radiation transport and energy disposition, fluid magnetohydrodynamics (MHD), atmospheric chemistry, and plasma stability analyses are necessary. Physical mechanisms that cause striations to decay are not yet well understood. Preliminary analysis show that plasma diffusion mechanisms

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appear to give lifetimes of the order of days or weeks whereas natural equatorial ionospheric scintillation data suggest lifetimes that are of the order of several hours.

Analyses have been published recently discussing theoretical aspects of satellite communications in a striated environment and will not be discussed here. There is also much work being done that is of a classified nature and limits the detail that this report may go into.

A computer simulation of a high yield/high altitude burst produces a plot of standard deviation of rms phase fluctuations to be observed at 10 GHz as a function of time (Refer to Figure E-4). It can be seen that fluctuations greater than 10 radians can be observed for roughly five hours or more. Modeling of a first order phase-locked-loop receiver derives a necessary BW for the system to suffer no decrease in BER as

$$BW \geq 1.35 \times \sigma^2 \text{ (Hz)}$$

where σ = phase standard deviation in radians

Assuming that $\sigma \sim 1/f$, for a SPADE/SCPC/PSK channel with a BW = 38 kHz, $\sigma \sim 170$ rad. That is, some degradation in BER can be expected to occur for about one hour after a burst or more. The effect on FDM/FM is not as bad as could be expected.

Here

$$20 \log (S/N) - \frac{20 \log (3.65 \times (BW)^{0.8})}{\sigma} \text{ (dB)}$$

For an FM channel of 40 MHz and a signal-to-noise degradation threshold of about 12 dB, σ is of the order of 10^6 and

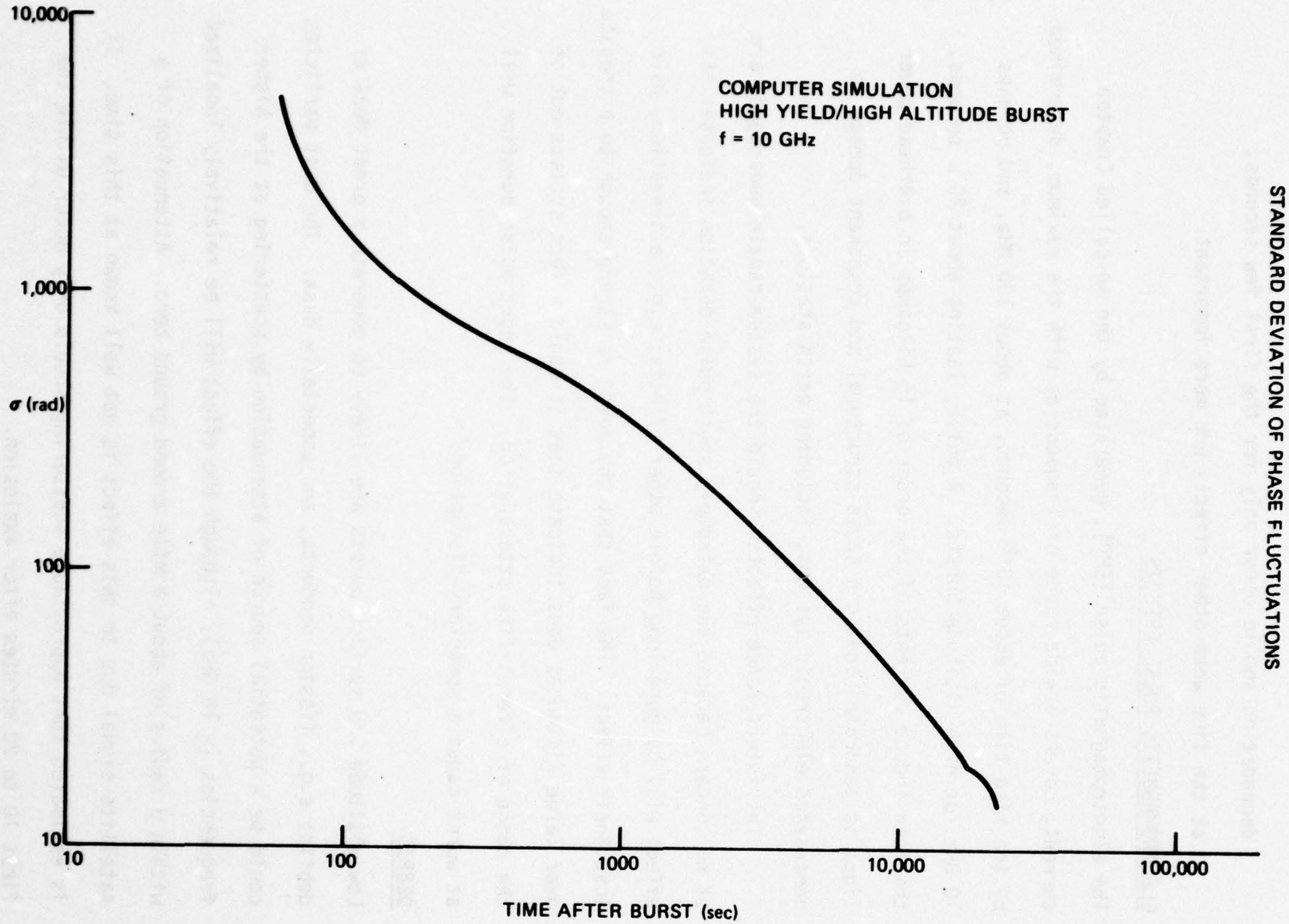

FIGURE E-4 STANDARD DEVIATION OF PHASE FLUCTUATIONS AS A FUNCTION OF TIME

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degradation should occur only for the first few seconds, at the time when other effects are more important.

3. <u>ELECTROMAGNETIC PULSE EFFECTS</u>

The electromagnetic pulse (EMP), generated by the so-called Compton current, covers a wide range of frequencies with the maximum, determined by the rise time of about 10^{-8} seconds, at about 100 MHz, and perhaps 10 GHz for high altitude bursts. A pulse, lasting about 20 μ seconds, that can induce currents of the order of 15 kiloamps in overhead power lines is generated that can cause structural and component damage to unhardened electronic systems, including earth stations.

The interference effects, should the system remain undamaged, are of no concern because the extremely short pulse duration indicates its effect will be gone long before other effects; e.g., attenuation, have lost their effect. The fact that the pulse is strong enough to propagate over large distances does indicate that it could affect systems out of the range of effects like attentuation. The short pulse duration will at worst cause a momentary disruption.

4. <u>DEBRIS</u>

Low altitude and surface bursts are likely to generate a great deal of debris; e.g., fission products, and especially dust. The dust particles could be a potential source of attenuation by scattering at the higher frequencies ($\geq$ 18 GHz), although the effect will be relatively localized within a radius of about a mile around ground zero. Attenuation of a satellite signal due to this effect is not well known at this time. It is estimated that appreciable scattering should only occur within the first 10 to 20 minutes after explosion.

5. SUMMARY

Estimates of the effects of nuclear explosions on communications within a domestic commercial framework are given for the more significant propagation disruptions that are likely to be encountered. Most of the effects are found to occur during the first 5 minutes or less after a nuclear blast and are limited to the immediate vicinity of the fireball and are not likely to cause serious disruption. One effect, phase scintillations due to electron density striation, is shown to have the potential to disrupt phase encoded digital communications for the order of an hour over areas as large as the contiguous United States, and thus could pose a problem for this type of digital transmission. The effect on FM is shown to be almost insignificant in comparison. The EMP energy, while a serious physical threat to electronic circuitry, does not pose any interference threat by way of propagation disturbances. The resultant effects are summarized in Table E-1.

TABLE E-1

Summary of Outage Estimates

Frequency Band	225-400 MHz	1.6-1.7 GHz	4.0-6.0 GHz	7.0-8.0 GHz	11.0-12.0 GHz	14.0 GHz	18-30.0 GHz
Signal Attenuation	1 min	5s	1s	1s	1s	1s	1s
Dispersion	10s	10s	10s	10s	10s	10s	10s
Multipath	neg	neg	neg	neg	neg	neg	neg
Polarization Rotation	10s	10s	10s	10s	10s	10s	10s
Doppler Shift	5s	5s	5s	5s	5s	5s	5s
Refraction	5s	1s	1s	1s	1s	1s	1s
Noise	5m	5m	5m	5m	5m	5m	5m
Phase Scintillation	7 hr	6hr	2hr	1hr	40m	30m	20m
Debris	neg	neg	neg	neg	neg	neg	10m

*Phase scintillation estimates are based on predictions at 10 GHz and do not extrapolate well below 4 GHz.

REFERENCES

1. Glasstone, Samuel and Philip J. Dalain, eds., "The Effects of Nuclear Weapons", U. S. Department of Defense, 3rd Ed., 1977.

2. Knapp, Warren S., et al, "Aids for the Study of Electromagnetic Blackout", AD/A-010 228, Defense Nuclear Agency, February 1975.

3. Hendrick, Ray W., Jr., "Propagation of Microwave Satellite Communications Signals Through Striated Media", DNA-4412T, for Defense Nuclear Agency by Mission Research Corporation, September 1977.

4. Wittwer, Leon A., "Satellite Communications in a Scintillated Environment", AFWL-TR-75-240, Air Force Weapons Lab, Kirtland Air Force Base, New Mexico, January 1976.

5. Personal Communication, Dr. Bill Bovary, Sandia Labs, Albuquerque, New Mexico, 9 March 1977.

APPENDIX F

EARTH STATION CONFIGURATION

1. GENERAL

Appendix F responds to item (3) of the Statement of Work: "consideration of a ground environment (mobile, transportable and fixed communications stations) which would be compatible with existing and/or planned satellite communications networks and would fully or partially meet with the needs of the Defense Civil Preparedness Agency".

An effective Civil Preparedness satellite communication network requires two basic classes of earth station for implementation. These classes of stations range from medium sized fixed and transportable stations to small, mobile and deployable stations. (Each type of station is described in the paragraphs that follow.) These stations are typical earth stations that are presently available for operation in the 6/4 GHz band of frequencies. Differences between the 6/4 GHz and 14/11 GHz stations involve details only of equipment size and design rather than fundamental concepts. For example, the antenna sizes identified for the fixed and mobile stations are expected to be reduced to 7 meters and 3.5 meters, from the 11 and 6 meters, if the 14/11 GHz satellite band is utilized.

Fixed stations, if they survive, can continue to provide communications through the blast period. This also would be true of a mobile station if it were in service at the time of a blast and it survived. Survivability of an unhardened station in a location close to a target

is extremely doubtful, and the stations are difficult to protect against over-pressure and thermal effects.

The advantage of a mobile station is that it could be located away from the primary target area in an underground or semi-hardened location to protect it from the blast effects. It then could be placed in service immediately to establish communications with the regional or emergency relocation center, either of which would dispatch it to the scene of the nuclear disaster. The length of time required to establish initial communications could be as long as fifteen minutes, and the length of time required to achieve operational communications from the disaster scene could be as long as a few hours.

2. REGIONAL AND NATIONAL CENTRAL STATIONS

As presently conceived, the Regional and National centers would be equipped with stations capable of handling more traffic than stations assigned at the State level. These Regional stations should be provided in two forms. In one form the station should be permanently installed at a hardened or at least semi-hardened site. In the other form, several stations should be packaged in a transportable configuration so that dispatch to an area in need could be accomplished expeditiously. These stations are similar, the only difference being that the prime movers and equipment would not be in service, but maintained and ready to respond to an emergency. Because of the antenna size necessary to support the traffic at the regional level, it would take approximately eight hours to place the transportable station into service after arrival at the scene of the emergency.

2.1 DESCRIPTION OF STATIONS

The description contained in this paragraph is directly applicable to stations which operate in the 6/4 GHz band. It is intended to provide background information about the earth stations which could comprise this network. Stations utilizing the 14/11 GHz band are essentially the same except that the antennas are somewhat smaller. Also, the vehicles associated with the transportable and mobile stations are lighter. A block diagram of such a compact domestic earth station is shown in Figure F-1.

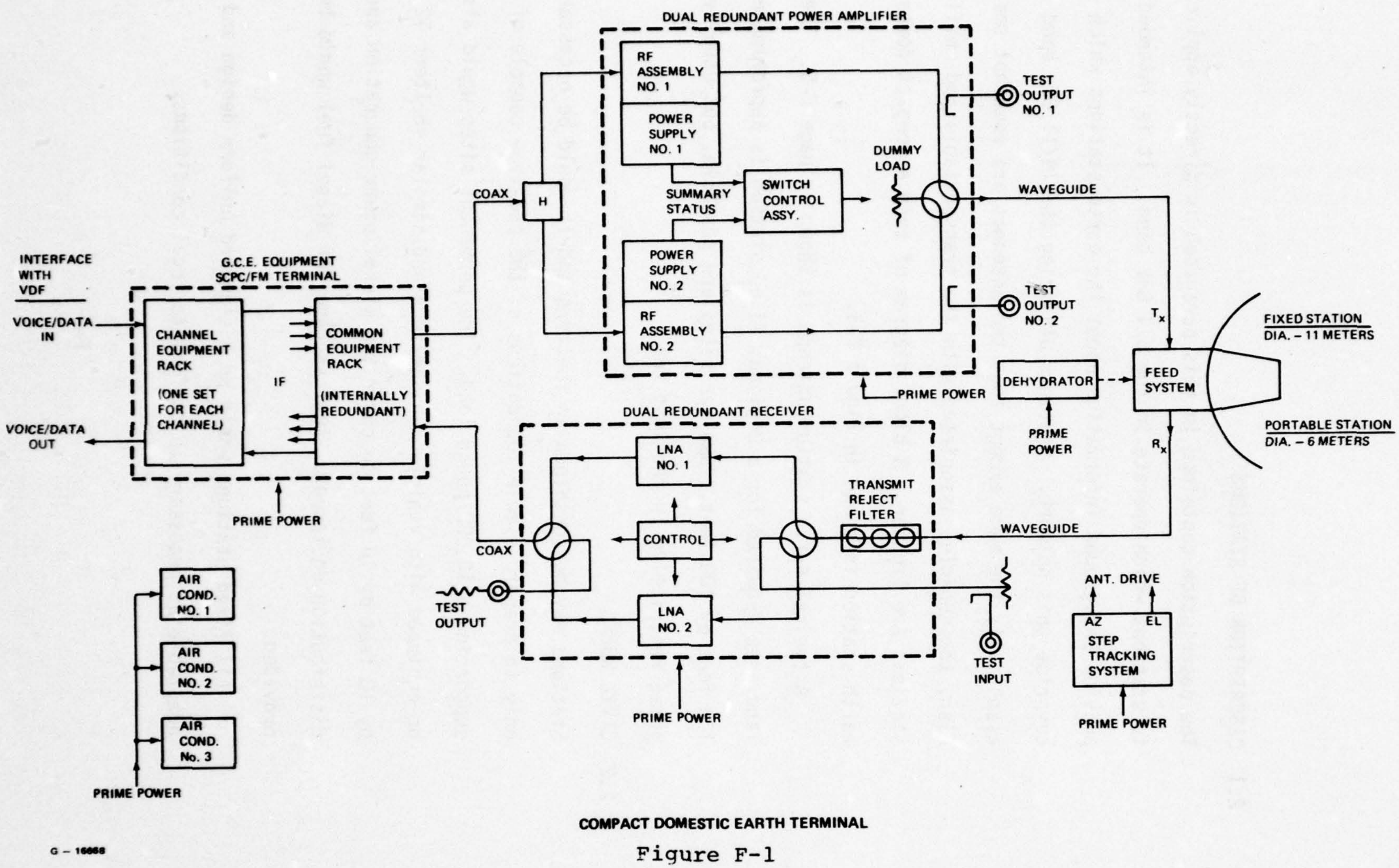
A typical earth station antenna is shown on page F-5. The land area required for a Regional fixed station is approximately 100 feet by 100 feet. Smaller sites are possible, but usually prove restrictive in the long run.

2.2 CIVIL WORKS

Stations may be contained in shelters and it would be necessary only to prepare simple foundations of the pad-type capable of supporting a 10,000 pound load. The permanent sites would also be equipped with vehicle sun shelters and similar shelters 12 feet by 10 feet by 10 feet to cover the diesel power generation and distribution equipment. Fuel storage for diesel fuel would be provided.

All fixed stations would be a standard uniform design and adaptable as necessary to conform to local conditions.

71



COMPACT DOMESTIC EARTH TERMINAL

Figure F-1

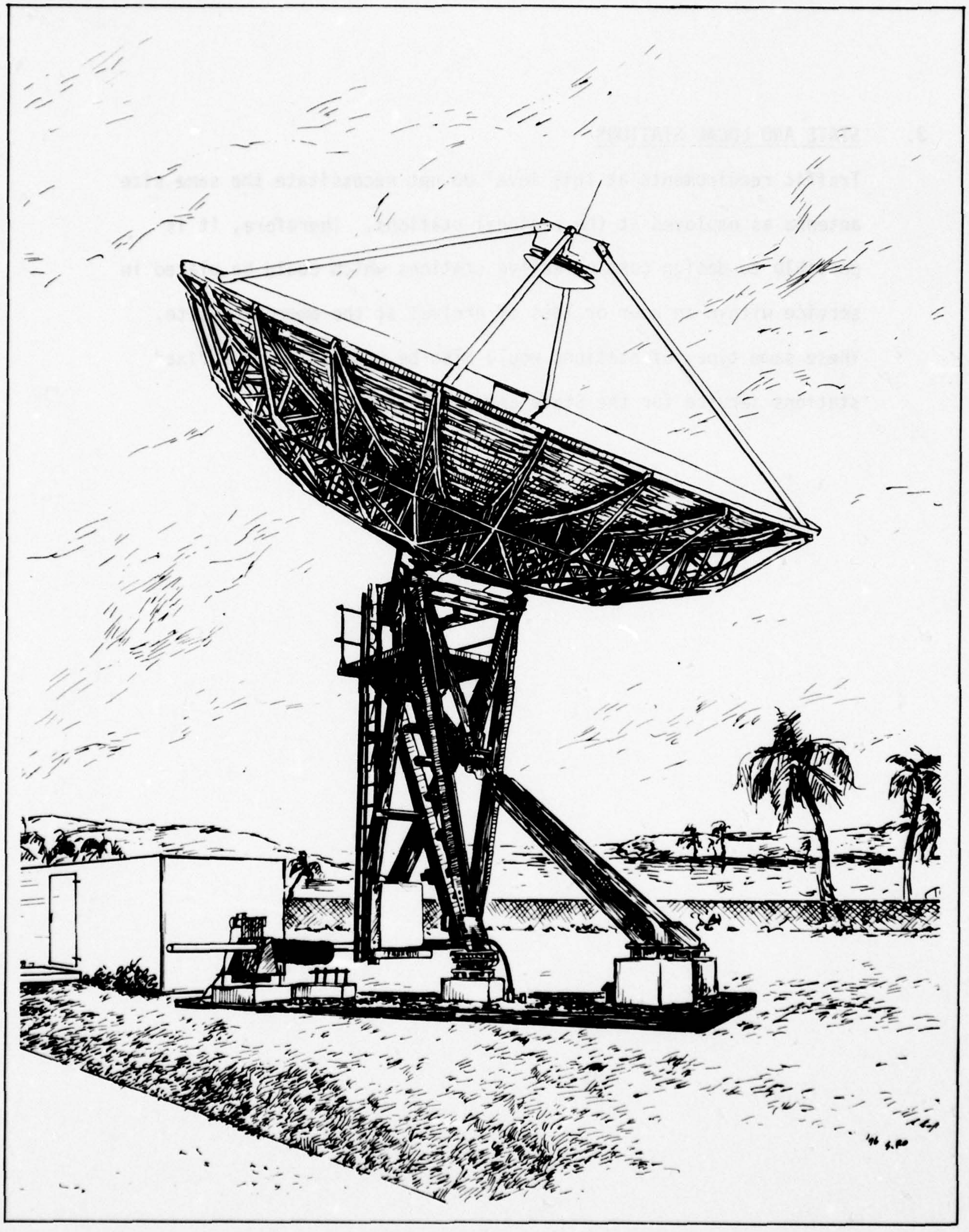


Figure F-1. Typical Earth Station Antenna

3. STATE AND LOCAL STATIONS

Traffic requirements at this level do not necessitate the same size antenna as employed at the regional stations. Therefore, it is possible to design cost effective stations which could be placed in service within an hour or less of arrival at the emergency site. These same types of stations would also be used to provide fixed stations service for the State and Local centers.

APPENDIX G

SATELLITE REMOTE SENSING

1. GENERAL

This section responds to item (6) of the Statement of Work, providing an "assessment of the application of remote sensing technology to the creation of a peacetime national resource data base, post attack damage, and a comparison between the two". Satellite remote sensing is the detection of objects or phenomena by spacecraft-borne imaging sensors. It is based on the principle that each object on or near the surface of the earth reflects or emits a distinctive radiant energy, and that space-borne sensors operating at the appropriate wavelength can use electromagnetic radiation to identify that object.

2. SYSTEMS DESCRIPTIONS

The satellite systems currently available to perform remote sensing operations are NASA's Landsat 2 and 3 and the National Oceanic and Atmospheric Administration's (NOAA) polar orbiting ITOS series and Geostationary Operational Environmental Satellite (GOES). They will be joined by NASA's Seasat-A in May of 1978 and NOAA's TIROS-N/NOAA-6 series later in the year.

2.1. LANDSAT

The purpose of this program (originally Earth Resources Technology Satellite Program) is to provide for a more efficient utilization and management of the earth's resources via satellite remote sensing.

To this end, intensive study and experimentation have been carried out in such disciplines as agriculture, rangelands, forestry, water resources, cartography, oceanography, and others.

The satellites operate in circular, sunsynchronous, near-polar orbits having an altitude of 916 km. This altitude allows them to complete one orbit every 103 minutes - 14 orbits per day, thus covering the whole earth every 18 days, or the United States in 4 passes. As there are two operating Landsats (2 and 3; Landat 1 was shut down following the March 1978 successful launch of the third satellite), coverage is arranged so as to overlap and provide total earth coverage every 9 days.

In order to provide for the repetitive acquisition of high resolution multispectral data, the Landsats carry a four-channel multispectral scanner (MSS).

This line scanning device uses an oscillating mirror to continuously scan perpendicular to the orbit track. As the MSS moves along in the orbit, six lines are scanned simultaneously in each of the four spectral bands (for each sweep the mirror makes). Radiation is sensed simultaneously by an array of six detectors in each of the four spectral bands.

In the Landsat system, those bands chosen as providing the greater amount of information without creating extremely large and difficult to manage data bases are:

Landsat Bands	Wavelength	Portion of Spectrum
4	0.5 - 0.6 μm	Green
5	0.6 - 0.7 μm	Red
6	0.7 - 0.8 μm	Near Infrared 1
7	0.8 - 1.1 μm	Near Infrared 2

Both operating Landsats provide spatial resolution of about 80 meters. Six-bit encoded detector output is formatted into a continuous 15 Mbps data stream. When operated over a ground receiving station, this data, as well as that from the Return Beam Vidicon (RBV) cameras, is transmitted in real-time to the ground station where it is recorded on magnetic tape. When operated outside a ground receiving station area, two wideband video tape recorders (WBVTR), each capable of reproducing data on command, and each with a 30-minute recording capacity, are implemented. (Landsat 2's tape recording capability is now operating in a restricted manner).

The most recently launched of the series, Landsat 3 has an additional band, the thermal infrared (IR) channel (band 8) which provides for intercomparisons of thermal data with simultaneous measurements at visible and near infrared wavelengths. This is done with a 240-meter spatial resolution. This third satellite also has the advantage of an improved RBV providing panchromatic imagery (0.5 - 0.8 μm) at 40-meter resolution. The RBV can be used either independently or in conjunction with MSS data, offering additional information.

NASA intends to orbit the next satellite in the series, Landsat-D, in 1981. This satellite will carry a high resolution (30-meter) sensing device, the Thematic Mapper, but will carry no on-board tape recorders. Data will be relayed to the White Sands Missile Range, the only station capable of receiving data at such high rates (84-100 Mbps), via the NASA/Western Union Tracking and Data Relay Satellite System (TDRSS). From White Sands, data will be relayed via a commercial domestic satellite (DOMSAT) to Goddard Space Flight Center for processing and from Goddard via DOMSAT to the EROS Data Center in Sioux Falls, South Dakota. This Department of the Interior facility produces Landsat imagery and computer compatible tapes (CCTs) and acts as the product distribution point.

In keeping with NASA's research and development charter, the Landsat series is experimental in nature, with no provision yet made for a follow-on satellite to the Landsat-D which is planned for flight in 1981 and which has an expected lifetime of 2 to 4 years. Even assuming the best, as the system is now planned there will be no continuity of service after 1985.

As mentioned above, orbital altitude forces an 18-day global coverage period; having two appropriately spaced satellites permits the same area to be overflown each 9 days. Therefore, in a post-attack time frame there is a possible maximum 9-day data acquisition delay (assuming no cloud cover and two satellites). Although it is estimated that in the 1979 time frame Landsat data

products will be available 4 to 7 days after imaging, the current time lag between acquisition and product availability is 3 to 6 weeks. No doubt special arrangements could be made for rush processing of data, and the current "polished" product format could be foregone.

Landsat data products are well suited to resource inventorying and change detection, in theory. Images taken in one orbital pass can be stored and compared with subsequently acquired versions. However, in reality the task is infinitely more complex.

To cite an example of the magnitude of the task of creating a data base suitable for change detection, the United States Department of Agriculture (USDA), the National Oceanic and Atmospheric Administration (NOAA) and NASA are currently involved in the Large Area Crop Inventory Experiment (LACIE). Its purpose is to demonstrate the applicability of remote sensing technology to monitor an important world food crop - wheat, on a global basis. With the Landsat data being used to provide the acreage component, and the yield component developed from World Meteorological Organization weather information by NOAA, the LACIE program was initiated in 1974. It is anticipated that it will be 1981 before a transition program can transfer the proven technology from LACIE to an operational system within USDA. A program to adapt LACIE technology to monitoring other important food and fiber commodities is foreseen for the mid- to late 1980's.

The use of Landsat for assessing materials deposition and land characteristic changes as a result of nuclear detonation is possible but, due to limitations of the sensor spatial and spectral resolutions and orbital characteristics of the spacecraft discussed previously, is not totally practical. Fallout depositions from a 5-MT surface blast in a uniform 15 MPH wind regime show an elongated fallout pattern extending downwind. The materials scoured from the crater, earth, concrete and the like depending on where the explosion occurred, and carried high into the atmosphere by the fireball, return to earth mainly in the form of siliceous particles of sensible size. They fall or move downwind according to their physical nature. The amount of material deposited is quite substantial and readily seen with the ground-level naked eye. Like desert sand, it can drift into gutters and sift into cracks under the action of wind and rain.

The fallout pattern can be thought of as the "shadow" of the mushroom cloud and stem. The elongated shadow shows mass deposition of 10 grams/ft^2 out to 70 mi. downwind, 1 gr/ft^2 to 140 mi., and 0.1 gm/ft^2 to 260 mi. The cross wind materials deposition at 0.1 gm/ft^2 is approximately 60 mi.

The spectral characteristics of the deposition materials will not change drastically from the materials' color prior to the detonation even though there is likely to be some charring due to the intense heat. The sand-like material carried downhill

will not appear significantly different to the naked eye. With the spatial deposition and spectral characteristics described above, it is unlikely that Landsat will "see" deposited materials sufficiently, except immediately at the crater. However, should new earth viewing satellite sensors become available in the early 1980's, unproved spatial and spectral characteristics may warrant further investigation of their use for post-detonation materials assessment.

2.2. GOES

Geostationary Operational Environmental Satellite (prototype called Synchronous Meteorological Satellites, SMS-1 and SMS-2) provides for high resolution visual and infrared imaging over areas of North and South America and the surrounding oceans every 30 minutes, or more frequently when required; data collection from remote observing platforms; broadcast of prepared weather and satellite information via the WEFAX system.

There are two operational satellites in this series - GOES-1 at about 135°W, covering North America and the Pacific Ocean to west of Hawaii; GOES-2 at about 75°W, observing North and South America, the Atlantic Ocean and parts of the African west coast.

The principal instrument aboard the GOES is the Visible and Infrared Spin Scan Radiometer (VISSR) which is a telescope scanning in a west-to-east direction with each spin of the spacecraft. A precision latitude stepping mechanism operates between spins, bringing the entire disc of the earth into view.

This instrument, like the Landsat MSS, observes in both the visible (0.55 - 0.75 μm) and infrared (10.5 - 12.7 μm). The infrared channel scans one line in each spin, giving approximately 8-km resolution at nadir (the point on earth directly below the spacecraft). The visible channel makes eight simultaneous scans of roughly 1-km resolution during each spin.

Typical GOES applications are cloud cover analysis, wind analysis from cloud motion, severe storm warning and hurricane tracking. The visible and infrared sensors operate outside the portion of the energy spectrum in which gamma radiation is found.

Recent satellite images from GOES 1 (June 18, 1977) have clearly shown massive dust clouds moving across the drought areas of the Sahara in Africa and out into the Atlantic. The dust stretched approximately 4,000 by 700 miles and topped at 15,000 feet. The ability to resolve dust clouds (down to 1 kilometer in diameter) and the further ability to view an area at least every 30 minutes makes the GOES satellite system a prime candidate for observing blast clouds and their subsequent movements. The presence of natural cloud cover will inhibit the ability of GOES to track blast clouds resulting from nuclear weapons with fields less than 100 KT since the cloud height will not necessarily rise above the natural cloud formations. Larger surface blasts will suck up more debris to a greater height and should be clearly visible.

2.3. ITOS

The ITOS series of satellites is presently represented by two operational spacecraft: NOAA 4, launched November 1974 which currently is in a standby mode, and NOAA 5, launched July 1976. Visible and infrared imagery is taken at spatial resolutions ranging from 1/2 to 4 miles. This provides information for analyses of cloud cover; fog distribution; ocean currents, temperature and waveheights up-welling; storm-tracking including hurricane and severe weather; measurement of wind, precipitation, temperatures and solar output.

The ITOS series will be replaced by the TIROS-N series beginning in mid-1978.

2.4. TIROS-N

This is the prototype of NASA's new polar orbiting satellite series which will be known as NOAA-6, NOAA-7, etc., after launch. This is a follow-on program to the ESSA, ITOS 1 and NOAA-1 through 5 satellites. Among other objectives, these satellites obtain temperature and humidity profile measurements of the atmosphere and provide frequent high resolution visual and infrared observations of the earth's surface and cloud cover. When the new polar orbiting system becomes operational, two spacecraft will be in an operational mode at all times. Initially, TIROS-N will have an 870-km altitude, and NOAA-6, an 830-km altitude.

A study carried out by the U. S. Army Electronics Command White Sands Atmospheric Research Laboratory, proved the feasibility of utilizing the NOAA-4 VTPR (veritical temperature profile radiometer) radiance measurements to determine wind profiles to satisfy the Army's requirements for high-altitude wind data, as the primary meteorological input in nuclear fallout predictions.

With this series as well, the sensors operate in a region of the energy spectrum, the visible and infrared, inappropriate to gamma detection.

2.5 SEASAT-A

This satellite to be launched in May 1978 is designed exclusively for monitoring oceanographic data such as sea surface temperature, surface winds, sea-ice, wave and wave spectra measurements, and coastal processes. Although one of its instruments, the Synthetic Aperature Radar (SAR) will be operated experimentally over land to test the ability of radar to add to Landsat data, there would appear to be little application to DCPA's mission.

3. SUMMARY

This brief description of the currently available and planned operational and experimental remote sensing satellites indicates that (1) their use by DCPA for resource data base inventorying for the purpose of change detection monitoring would be inadvisable at this time, and (2) the type of instrumentation carried on-board is, in most cases, unsuitable to detect and/or track nuclear fallout. However, the GOES ability to track dust clouds seems a potentially promising application and may profit

from further study.

However, the use of remotely-sited automated instrumentation transmitting radiation data via communications satellite appears to offer an attractive area for further study at this time. This is treated more fully in Appendix H.

APPENDIX H

FALLOUT MONITORING VIA SENSOR MONITOR TERMINALS

This section responds in part to item (7) of the Statement of Work: plan for (a) in-depth analysis of the identified requirements and (b) design of demonstration/operational communication network..."

Monitoring methods and the reporting structure which DCPA currently employs in conjunction with State and local officials rely heavily on the feasibility of field measurements made by hand-held instruments. Of course, these measurements would not always be available in an immediate post-attack or post-nuclear disaster situation.

Recognizing the inherent limitations of humand-based monitoring and reporting systems, the DCPA and its predecessor organization, the Office of Civil Defense, have for several years been investigating the possibility of establishing automated detection/reporting systems. Such systems provide the obvious advantage of lessened reliance on, and consequently lessened danger to, human monitors. Additionally, data can be retrieved over wide areas in a very short period of time and relayed to decision-making centers with improved speed and reliability.

As early as 1963, one research organization examined this issue, determining a nationwide monitoring configuration based on fixed stations in those areas having an aggregate of critical resources such

as large population, railroad yards, hospitals, major electrical, water, and telephone facilities, and radio transmitters. Such a spacing does not cover certain sections of the west and mid-west and would not provide for monitoring of fallout moving in an easterly direction. The report found that approximately 470 stations would be required for the coverage.

Further study by the same organization several years later suggested an automatic attack-effects information system, sharing National Warning System (NAWAS) communication links, which would monitor both pressure and radiation. A series of sensors would collect and relay data to "concentrator" points where it would be reduced if need be, and transmitted to the appropriate Emergency Operating Center (EOC), thence to the Regional and National levels - in hierarchical fashion. Several spacing schemes were investigated to provide adequate CONUS coverage, the most ambitious scheme indicating the requirement for almost 14,000 sensors to cover virtually all population and land areas.

Several Federal and State agencies have deployed over 50,000 environmental data collection sensors nationwide. Of these operational networks, many rely on telemetry for the real-time or near real-time, transmission of data to centralized locations. Many more are amenable to telemetering, and, recognizing the money- and time-saving aspects, as well as the advantage of management decisions made in real-time, the trend toward automatic data collection is growing.

The relatively new technology of satellite communications can provide the next logical step in progression from monitoring networks

which are completely human-dependent to those placing emphasis on automated collection and reporting. Satellites are currently being used as relay points for remotely-collected environmental data. The basis for such a network has already been laid in a pilot program undertaken between COMSAT General Corporation, the U. S. Geological Survey and Telesat Canada. In this program, Telesat Canada is providing satellite capacity on one of its Anik domestic telecommunication satellites. The Geological Survey provides hydrological sensor stations distributed in this country in Pennsylvania and Oregon, as well as two in Canada. COMSAT General is responsible for the 6 GHz sensor monitoring terminals especially designed for this program. For the U. S. portion of the program, data transmitted via the Anik satellite is received at COMSAT General's Southbury, Connecticut Earth Station.

In the field, Sensor Monitor Terminals (SMT's) are placed adjacent and wired to hydrological monitoring instruments. These SMT's comprise four elements: the sensor interface and modulation package, radio frequency electronics, battery package, and transmit-only antenna. The technical characteristics are as follows:

SMT Transmitter Power	1 W nominal
Antenna Diameter	4 ft.
e.i.r.p.	33.5 dBW
Modulation	Binary, non-coherent FSK
Channel Bandwidth	3 kHz
Transmit Frequency	5950 MHz
Type of Transmission	random burst mode

Message Transmission Rate	1, 2 or 4 messages per hour
Information bits per message	64
Preamble, telemetry, etc. - bits per message	180
Bit rate	1 kbps
Burst duration	244 msec.

The SMT's are powered by two 12-volt batteries which operate in a continuous three-month mode.

Measuring instruments used in the pilot program are an automatic digital recorder to determine water level and a multi-channel instrument which collects various chemical and physical data to determine water quality. The water level instrument is fitted with electrical output contacts which interface with the SMT to provide for data transmission. The water quality instrument provides continuously available analog data to the SMT's analog-to-digital converter.

Interface between the instruments and the SMT is controlled by a micro-processor for message formatting and encoding. This use of a software controlled micro-processor to control the data acquisition and transmission cycle, allows flexibility in adapting the SMT to use with different types of sensors or to different operating modes.

In fact, the SMT makes no distinction as to the type of sensor employed or the type of data being collected; that is a software-related issue. The technique is currently being used to collect hydrologic data, noted above, as well as snowpack and meteorological data. This, together with the existing and operational commercial-quality systems which

simultaneously monitor air pollutants and meteorological conditions that affect their diffusion, water quantity and quality, and other environmental parameters, and rely on telemetry for data transmission from unmanned sites, and which could utilize communications satellites as the relay, exemplify the widespread interest in this area.

Such a system would be applicable to the DCPA mission to collect and disseminate nuclear fallout data for administrative and operational needs. This could be provided for by a dedicated radiation instrument network or by subscription to a service which provides the information in final format.

In the first network, instruments and SMT's are sited following specific DCPA criteria. Data is formatted and encoded in the field and transmitted via a communication satellite to a receive antenna located at one or more Regional centers, most probably Region 2 Headquarters in Olney, Maryland, since this center would function as Alternate National Headquarters in the event of nuclear attack.

The second alternative, which may prove to be more economical and efficient, would be to subscribe to an information service. The service provider would have full responsibility for data acquisition, processing, analysis and distribution.

Figure H-1. Typical Sensor Monitor Terminal

August 1976

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THE APPLICABILITY OF SATELLITE TECHNOLOGY TO DEFENSE CIVIL PREPAREDNESS, by COMSAT General Corporation. Contract No. DCPA01-77-C-0239, Work Unit 2214E. 30 June 1978, 86 pages. Unclassified.

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COMSAT General Corporation, Washington, D. C. 20024

THE APPLICABILITY OF SATELLITE TECHNOLOGY TO DEFENSE CIVIL PREPAREDNESS, by COMSAT General Corporation. Contract No. DCPA01-77-C-0239, Work Unit 2214E. 30 June 1978, 86 pages. Unclassified.

This study assesses the applicability of satellite technology to the DCPA mission. Surveys of currently-available and planned communication and remote sensing satellite systems are presented. A section on post-nuclear-blast propagation conditions is included. Conceptual satellite network plans one based on a dedicated network and one on commercial transponder leasing, are developed, leading to a plan for a preliminary Demonstration Network. The study concludes that a satellite-based Civil Preparedness Communication Network could support both peacetime and disaster-oriented requirements practically; that the use of remote sensing for

resource data base inventorying is presently inadvisable; that the 6/4 GHz band offers the best technical and most cost-effective means for initial implementation; and that use of remotely-located Sensor Monitor Terminals to collect and transmit radioactive fallout data to a central processing facility is feasible.

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